Chapter 4

Environmental Consequences

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4.1 INTRODUCTION

The 1997 Draft and 1998 Final EIS discussed impacts associated with pit reclamation alternatives. The information presented in this SEIS supplements those documents.

What has changed in Chapter 4 since the DSEIS?

Chapter 4 describes the environmental consequences of the Proposed Action and three alternatives. Based on additional data and public comments, the following changes have been made:

- Selected analyses in the Final SEIS have been updated since preparation of the Draft SEIS in 2003-2004, as indicated by more recent reference citations.
- The GSM 2004 annual report was used to update all figures. The 2006 annual report was used to update some acreages.
- Information on the 2004 earthquake and its effects on the area is provided.
- Additional wildlife species found or that may be found near the area were listed.
- The groundwater capture needed to meet groundwater standards at the mixing zone boundary for the Partial Pit Backfill With Downgradient Collection Alternative was changed from "95 percent capture efficiency" to "two groundwater capture systems, operating at combined efficiency of approximately 96 percent".
- The volumes of soil cover needed in the four alternatives were updated.
- The pit discharge rate was changed from 16 gpm to between 27 and 42 gpm for the Partial Pit Backfill With Downgradient Collection Alternative and from 32 gpm to between 25 and 27 gpm for the No Pit Pond and Underground Sump alternatives based on a new water balance model.
- The groundwater collection and treatment rate was changed to approximately 145 gpm for the Partial Pit Backfill With Downgradient Collection Alternative.
- The permanent loss of 158-159 acres was changed to 156-158 acres for the No Pit Pond and Underground Sump alternatives.
- Table 4-8 was added to show compliance with DEQ-7 Groundwater Standards and Nondegradation Criteria for the Partial Pit Backfill With Downgradient Collection Alternative for selected parameters.
- Reference was made that the property could be used as a wind farm.
- Measure 2a addresses backfill sources for the partial pit backfill alternatives.
- Measure 15 is now split into three submeasures. Measure 15a is the same as Measure 15 in the Draft SEIS. Measure 15b addresses the installation of an upgradient capture system. Measure 15c addresses the installation of a downgradient capture system near the east edge of the pit. Both Measures 15b and 15c apply to the partial pit backfill alternatives.
- All text, figures and tables were revised from data provided by GSM and various consultants.
- Text was corrected based on references.
- Nondegradation analyses were performed for the Jefferson River Alluvial Aquifer and Jefferson River Slough.

This SEIS addresses potential environmental consequences as a result of the Proposed Action, No Action and two other alternatives presented in Chapter 2. The

most important issue in this SEIS, as determined through scoping, is the potential impact to groundwater. The open pit is the principal facility affected by the actions and alternatives of this SEIS. The East Waste Rock Dump Complex is affected for alternatives involving backfill; waste rock to backfill the pit would be obtained by removing about 33 percent of the volume from the top of the East Waste Rock Dump Complex as shown in Figure 2-6. The footprint of the East Waste Rock Dump Complex would not change.

In addition, 13 percent of the footprint of the East Waste Rock Dump Complex is in the Rattlesnake Gulch drainage. This means that part of the seepage from the dump complex would infiltrate below the dump and mix with ambient groundwater in Rattlesnake Gulch. This groundwater moves down the drainage toward the Jefferson River alluvial aquifer. Most of the seepage from the pit would also move down the Rattlesnake Gulch drainage, if the seepage is not contained within the pit. Hence, the following analysis discusses the alternatives and issues of concern with respect to the pit and the East Waste Rock Dump Complex and associated potential impacts to the environment.

This chapter describes the direct, indirect, and cumulative environmental consequences (both adverse and beneficial) for each of the pit reclamation alternatives. Many impacts are the same regardless of the alternative; however, other impacts are directly dependent on the reclamation measures in a specific alternative.

The impacts are described based upon the change that would occur to the existing resource conditions described in Chapter 3 if the alternative were implemented. The analysis will focus on risks and uncertainties from implementing the various pit reclamation alternatives.

4.1.1 Assumptions

The impact analysis is based upon the following assumptions:

- The Stage 5B pit mining and pit reclamation alternative would be fully implemented as described in Chapter 2.
- Potential mitigation has been built into each alternative as part of the activity that would occur under that alternative. The impacts described for each alternative are, therefore, the residual impacts left after the implementation of mitigating measures.
- Monitoring and maintenance of the water capture and treatment systems would occur under all alternatives as needed to meet the requirements of the Montana Water Quality Act and other permits. The amount of effort required to maintain the systems and the certainty with which compliance is achieved may vary by alternative.
- Consequences of failure of each alternative will be estimated using the best available information. Risks and uncertainties are noted.

4.2 TECHNICAL ISSUES

4.2.1 No Pit Pond Alternative (No Action)

4.2.1.1 Design and Constructibility of the Alternative

Design and constructibility of the No Pit Pond Alternative were not evaluated in the 1997 Draft EIS.

4.2.1.1.1 Proven Design

Under the No Pit Pond Alternative, 100 feet of crusher reject would be placed in the pit as a sump, and two to three 100-foot dewatering wells would be installed to the bedrock contact. It is estimated that from 25 to 27 gpm would be pumped out of the wells (Telesto, 2006).

As described in Section 4.2.1.3 and the pit backfill analog study (Gallagher, 2003c), pits have been backfilled in Montana and elsewhere. Several pits in Montana and other states have been mined below the water table and have been partially backfilled above the water table level. Active dewatering has been conducted in partially backfilled pits.

It is technically feasible to haul backfill and install wells in a pit at closure. Backfilling by hauling to the bottom of the pit and end dumping and dewatering the pit under the No Pit Pond Alternative is a proven design. Backfill maintenance problems after construction of the alternative are described in Section 4.2.1.3.

4.2.1.1.2 Ability to Construct the Alternative at GSM

At closure, GSM would haul the crusher reject between 725 and 825 vertical feet down into the pit from the eastern rim of the pit at the 5,350-foot elevation. GSM's safety policy would require special conditions, such as truck load limits, to be imposed during the backfill operations because of safety concerns with driving fully loaded trucks down the steep pit access road. The 5,700-foot elevation safety bench would have to be maintained. A 1.3-acre working surface would be created on the backfill. A safety berm would be installed on the working surface to protect workers and the dewatering wells.

Two to three dewatering wells would be constructed through the 100 feet of crusher reject to the bedrock contact. Drilling through unconsolidated waste rock is more difficult than drilling through solid rock, but can be done using special equipment. Over 100 feet of backfill have been hauled into pits reclaimed in Montana and elsewhere. Dewatering wells pumping 25 to 27 gpm have been drilled in at least 100 feet of weathered waste rock backfill at GSM and elsewhere (Gallagher, 2003c).

There would be minimal problems developing and implementing the No Pit Pond Alternative at closure as described, because only 111,000 cubic yards (167,000 tons) of crusher reject and two to three wells would be needed. Pit highwall and dewatering well maintenance problems after construction of the alternative are described in Sections 4.2.1.2 and 4.2.1.5, respectively.

4.2.1.2 Pit Highwall

Ground movement in the mine area was analyzed in the 1997 Draft EIS, Chapter IV, Section IV.A.1.a. No ground movement affecting stability in the pit or waste rock dump complex areas have been identified through 2006.

This section addresses both pit highwall stability and pit highwall maintenance requirements for the No Pit Pond Alternative. Additional geotechnical studies on pit highwall stability were conducted for this SEIS (Telesto, 2003d and 2003g). In 2005, GSM conducted reviews of the pit highwall information. The conclusions support the overall stability conclusions found within the Draft SEIS (Brawner, 2005; Golder, 2005). This section will concentrate on observations from 25 years of mining at GSM and on new stability evaluations for the open pit area only.

4.2.1.2.1 Stability Observations at GSM (1981-2006)

During the past 25 years of open pit mining at the site, many slope design studies have been performed (Golder, 1995a-l, 1996a, 1996b; Seegmiller, 1987, 1988; Telesto, 2003d, 2003f). There have been several pit slope failures in connection with on going mining activities. Little information is available for pre-1992 slope failures. The following list provides volume and timeframe estimates for selected post-1992 slides (Telesto, 2003f; Brawner, 2005; Golder, 2005):

- North highwall zone – 600,000 cubic yards in 1995 to 1997.
- Southwest highwall – 500,000 cubic yards in 1999.
- Upper west highwall zone – 200,000 cubic yards in 1999.
- Southeast pit highwall – 10,000 cubic yards in 2001.
- Expanded ramp pit highwall – 50,000 cubic yards (Brawner, July 2002).
- Expanded ramp pit old pit highwall – 10,000 cubic yards (Brawner, September 23, 2003).
- Northwest pit highwall – 310,000 cubic yards on August 31, 2004 where bedding planes that dip into the pit at 30 degrees intersected the Lone Eagle Fault. Movement in the area was being monitored prior to the failure.
- Northwest pit highwall –33,000 to 47,000 cubic yards on June 8, 2005. The slope between the 5,200-foot and 5,450-foot-elevation benches failed and remobilized the failure between the 5,450-foot-elevation bench and the 6,030-foot-elevation highwall crest. The toe of this failure on the 5,200-foot-elevation bench evidently involved the intersection of the Corridor Fault and the Lone Eagle Fault (Golder, 2005).

- Northwest 4925 Wedge - On January 30, 2006, a 47,000 cubic yard wedge mobilized between the 5,200-foot and 4,925-foot elevations due to intersecting high angle structures in the northwest corner of the pit. A catch bench and a rock-fall protection barricade were installed so that mining could continue.
- Switchback Failure - On April 5, 2006, a 133,000 cubic yard highwall failure resulted in the loss of the Number One Switchback from the Main Pit Ramp on the north highwall. The failure was caused when a Lone Eagle type fault intersected a bedding plane fault on the 4,925-foot elevation and was subsequently pressurized by a large precipitation event, 2.7 inches in 24 hours. Consequently, the main ramp was relocated east into the footwall of the Mineral Hill Breccia Pipe.

These failures ranged from small scale bench and multi-bench failures to a large-scale wedge failure of the southwest highwall of the Stage 2 pit. These failures and smaller scale movements were a direct result of mining activities and ceased within days after mining operations moved to different areas of the pit (Paul Buckley, GSM, personal communication, 2003). The largest contributing factors to these failures were conventional blasting, unfavorable structural orientations, such as faults or bedding planes that were exposed by mining, water pressure in joints and fractures, and vibrations from truck hauling, excavating, and dozing.

Highwall failures can be mitigated during operations using a variety of methods as follows:

- Mining to remove the area of concern.
- Flattening of the highwall in the area of concern to reduce the forces tending to cause movement.
- Buttressing the toe of the highwall to reduce forces that tend to cause movement.
- Providing artificial support such as rock bolts and dowels.
- Horizontal drain holes to reduce the hydrostatic pressure which tends to cause movement where unfavorable structural geology exists.

At times during operations, all of these methods or a combination of methods have been used to mitigate the impact of unstable sections of the pit highwall.

One factor influencing pit highwall stability that can potentially be controlled is the impact of blasting. Reducing over break effects (*i.e.*, fracturing and damage to the pit highwall beyond the extent desired for mining) leaves the inherent strength of the rock and geologic structures at the pit highwall in a stronger condition. Therefore, controlling the impact of blasting can be considered a pit highwall stabilization technique.

Pre-splitting is one of several techniques used to control over break. Pre-splitting is similar to blasting techniques used in the rock quarry industry to remove blocks for

building stone. With pre-splitting, a row of holes is drilled along the final excavation line and loaded with a special grade of explosive. These holes are fired prior to the production blast to create a fracture line at the excavation limits. The idea of pre-splitting is to isolate production shots from the remaining rock formation by forming a crack along the designed highwall. Although good over break control results cannot be expected in all geologic formations, a carefully planned blast design can minimize over break in even the most severe conditions.

Pre-splitting works well at GSM (Paul Buckley, GSM, personal communication, 2003). Pre-split blasting techniques have been utilized since January 2001 and would be used throughout the remaining mine life of Stage 5B. Once mining activities for Stage 5B have been completed, approximately 58 percent of the pit highwall would have been mined by pre-split blasting techniques, from the 5,700 bench extending down to the 4,550 bench.

The impact of pit highwall instability during operations would range from minimal to the loss of a substantial portion of the ore reserve. For example, during mining of the Expanded Ramp Pit, two substantial highwall instabilities developed (see above). However, the mitigation for these did not result in the loss of ore reserves, although sections of the pit were redesigned.

Stage 5B would excavate several areas known for unstable ground conditions. However, a diligent slope stability program, including monitoring, geologic mapping, controlled blasting, dewatering, and scaling, would continue to mitigate poor ground conditions as they arise. This would reduce the likelihood of raveling and sloughing impacting long-term operations in the pit bottom. As an added safety measure, the safety bench located at the 5,700-foot elevation would separate the upper north highwall of the pit, where pre-splitting was not used, from the pit bottom. Most of the past failures were caused by, or were associated with, conventional blasting and excavation activities. Such failures would not be expected to occur after mining ceases.

The zones of past pit highwall instability that will remain after completion of the Stage 5B Pit are located above the 5,700-foot safety bench. Monitoring of these zones is on going and no impact from current mining has been recorded.

In summary, past pit highwall instability has been largely attributed to mining activities intersecting unfavorable structures. Characteristically, ground movement has subsided within days after mining operations have moved away from the zone of instability. For this reason, these types of instability and frequency of occurrence would not be typical after closure at GSM, with any pit reclamation alternative being evaluated.

Based on 25 years of observation, the slope failures that have occurred in the non-active mining areas of the GSM pit have been sloughing failures with localized raveling of benches (*i.e.*, the benches lost their blocky shape). Portions of the outside

edges of mine benches have broken off and the intersection between the flat portions of the benches and highwall have filled with these rocks forming talus slopes. The impressions of the benches are still visually evident over most of the pit highwall. These failures have occurred predominantly during the spring and fall months following freeze and thaw cycles, spring melt of accumulated ice and snow on the pit highwall, and following large rainstorm events. These instabilities are typically small-scale and are similar to those observed on mountain slopes along highways.

Experience has indicated that raveling is more common on the newly mined pit highwall and would decrease as the pit highwall matures. On the south side of the pit, the pit highwall movement has been basically dormant for the past 10 years. Much of the north side of the pit, including a zone of instability on the northwest highwall, had been dormant for 6 to 10 years until a failure occurred in 2004 (see above). Both failures were initiated by mining activities in that area. Based on these observations over the mine's life, it is expected that raveling and sloughing would occur over time. The majority of raveling highwall rock would be caught on safety benches resulting in angle of repose surfaces less than 100 feet long and would not cause problems in the bottom of the pit. This type of instability would be slow in movement and progression, although occasionally rocks would fall off safety benches and roll to lower portions of the pit.

After closure, large-scale, multiple-bench wedge failures in the Stage 5B Pit that could destroy dewatering wells would be unlikely (Telesto, 2003d). This prediction is based upon the increase in the competency of the rock that is mined beneath the Corridor Fault and the resulting rock quality due to the improved blasting methods implemented by GSM, which have decreased blast damage to the pit highwall. To further reduce the possibility of a wedge failure, GSM incorporates information regarding local bedding, faulting, and fractures directly into pit designs and excavation. Even with the predicted long-term stability, to be conservative in the following section of this SEIS analysis, the agencies have assumed occasional failures.

4.2.1.2.2 Pit Highwall Stability

The results of the failure modes and effects analysis for the No Pit Pond Alternative in the 1997 Draft EIS, Chapter IV, Section IV.A.6.a indicated that most of the identified modes of failure have a low to very low probability of occurring. Moderately likely failure modes are primarily associated with potential block slip movements in the pit. The only failure mode that would likely occur is occasional localized failures similar to those that can be observed in the highwall today.

For this SEIS, GSM conducted an investigation into pit highwall stability for the pit reclamation alternatives (Telesto, 2003d). The study focused on the Pit Pond Alternative, which has been dismissed in Section 2.5.4, and on the partial pit backfill alternatives. Because of the similarity in geometry between the alternatives, results for the Pit Pond Alternative are directly applicable to the No Pit Pond and Underground Sump alternatives.

For this investigation, rock and soil samples were collected to determine soil classification and geotechnical properties of the rock and soil, using standard industry accepted practices (Telesto, 2003i). The geotechnical properties were then used for modeling the reclamation alternatives for the GSM pit.

Block failure analysis was not conducted because the geology reports for GSM did not indicate the presence of a weak soil layer at the base of the slope, and because most of the pit is constructed in an anticline (*i.e.*, the formations dip away from the pit) (GSM, 1996c). Most high angle faults running through the pit dip into the center of the pit, the Range Front Fault dips steeply away from the pit on the east and the Corridor Fault dips gently towards the east across the upper portion of the pit. These configurations make the possibility of block failure less likely than a circular failure. Damage to a reclamation alternative as a result of massive block failure is unlikely.

Circular failure analysis was chosen to model the potential for massive failure of the pit that would damage or destroy the reclamation alternatives because of the site-specific geology of the pit. Pit highwall stability was modeled to estimate the potential for massive failure in the circular failure mode for each reclamation alternative. SLOPE/W version 5.04, a state of the art model for evaluating slope stability, was used (GEO-SLOPE International, Ltd., 1991; Telesto, 2003d). The relationships between the pit highwall, faults, joints, and bedding angles are conducive to using the circular failure analysis, which overestimates the chance of highwall failures. Circular failure would have to occur across the bedding planes and geologic structures. In circular failure analysis, structures are ignored and the material is treated as unconsolidated. The analysis overestimates the chance of highwall failure because it ignores a fundamental strength component in the analysis (Telesto, personal communication, 2005).

Failure planes typically follow structures. Bedding in much of the pit and a 200-foot-thick latite sill in the northern part of the pit dip away from the pit. However, along portions of the south and west pit highwall, beds dip gently into the pit. Adverse bedding orientation, usually in conjunction with structures or jointing intersections, have only contributed to small slope failures in an area confined to the west and northwest corner of the pit, in a zone in the general vicinity of the Corridor Fault. Historically, failures in the pit have generally been small and have occurred along steep northeast trending faults due to mining activities.

GSM prepared additional stability analyses since the Draft SEIS focusing on the stability of the pit highwall (Golder, 2005). Rock mass stability analyses indicate adequate factors of safety with respect to rock mass failures for the highwall. Failure analyses indicate little potential exists for structurally controlled failures of the highwall, with the exception of the existing failures in the upper west and northwest highwalls (Golder, 2005). In these areas, raveling and small wedge failures could occur. Such failures would be limited in scope and would not damage or destroy the reclamation alternative.

As mentioned in Section 3.2.2.2, stability analyses use factors of safety to estimate the inherent stability of the pit highwall. A factor of safety of 1.0 is considered stable. Factors of safety greater than 1.0 indicate higher pit highwall stability.

The model was run assuming Stage 5B without backfill and with the groundwater level still drawn down below the pit bottom as a result of operational dewatering (Telesto, 2003d). In the No Pit Pond Alternative, the pit would be backfilled with 100 feet of crusher reject from 4,525 feet to 4,625 feet, which would reduce the overall height of the 1,875-foot-high highwall and increase the stability slightly. The water table would be maintained as close to the final pit bottom as possible, which would make it almost as stable as the dewatered Stage 5B Pit. The results of these failure analyses showed that the pit highwall would be stable, and the factors of safety would range from 1.17 (based on higher than anticipated input values) to 1.60 (based on expected analysis input values).

To be on the safe side, the Pit Pond Alternative was analyzed for stability because, with the highest water level and the least amount of backfill, highwall stability problems would be more likely to occur than with the other alternatives. The pit highwall stability for the Pit Pond Alternative following formation of a pit pond decreased from 1.17 to 1.16. A change of less than 0.1 in the overall factor of safety is not important considering the accuracy of this type of analysis. Based on these stability analyses, the factor of safety change would be negligible compared to the dewatered Stage 5B pit. This conclusion agrees with the results for the No Pit Pond Alternative in the 1997 Draft EIS.

The values for the pit highwall are less than the industry-accepted 1.3 short-term and 1.5 long-term factors of safety. However, there is a 97 to 99 percent probability that all the possible strength input parameters would be larger than estimated, resulting in higher factors of safety than calculated in the analysis. Therefore, the expected 1.6 factor of safety value is greater than the 1.3 short-term and 1.5 long-term factors of safety and should be considered as the expected factor of safety for the pit highwall.

Physical and chemical weathering of the pit highwall would not impose an immediate change to the geotechnical analysis presented (Telesto, 2003d). Short-term physical weathering of the highwall appears to be dominated by the effects of blasting, which do not extend far into the highwall, especially below the 5,700-foot safety bench where pre-split blasting has been used. Freezing and thawing would largely control pit highwall physical weathering rates over the long term. Chemical weathering from sulfide oxidation should not extend beyond a thin layer on the exposed surfaces of the highwall and fractures. Exposed sulfide-rich highwall rock in the pit would continue to oxidize through infiltration and percolation of precipitation and seeps regardless of the effectiveness of dewatering. Locally, the oxidation of iron hydroxide might enhance stability through iron oxide cement formation. Thus, physical and chemical weathering would not cause catastrophic failures in the pit highwall (Telesto, 2003d).

In addition to the circular failure analysis, Telesto (2003a) completed an addendum to provide discussion and historical perspective on the possibility of localized pit highwall failures not previously addressed by Telesto (2003d) that would likely occur after closure. The addendum discussed both failures that have occurred during mining operations and failures that can be expected to occur after closure. The addendum discussed the details of the geologic setting and pit slope failures at GSM from 1981 through 2003.

Stability of the highwall after closure in a dewatered pit would greatly depend upon highwall rock integrity. Seeping and fractured areas would generally tend to be less stable unless secondary processes cause cementation of the materials in such zones. Pit highwall slopes would continue to undergo alternating periods of rock raveling and sloughing and quiescence for years after mining has ceased. As the pit highwall is acted on by gravity and the rock fracturing forces of freeze-thaw cycles, the steeper pit highwall would ultimately shed material to form talus slopes at its base, trending to a less steep highwall at the higher elevations. The 1,775-foot pit highwall should achieve equilibrium in 10 or fewer years after closure, with further minor adjustments in wet or above average freeze and thaw cycles and in years with earthquakes.

Seismic effects on stability were evaluated in the 1997 Draft EIS, Chapter IV, Section IV.A.1.a and no adverse effects on highwall stability were identified. No further evaluation of earthquake effects was made for the Draft SEIS. A seismic evaluation, including pseudo-static analysis information, was conducted for the Draft SEIS, which corroborated the 1997 Draft EIS analysis (Telesto, 2003d).

GSM conducted additional studies at the site after a 4.0 magnitude earthquake occurred nearby on June 28, 2004 (AMEC, 2004). It was felt at the mine, but no damage was done and no highwall instability occurred.

Mineralogical, geochemical, and geological data and observations were reviewed and analyzed relevant to the geotechnical evaluation of pit highwall stability at GSM after pit closure (Telesto, 2003d). The highwall stability at GSM has been compared to other sites with similar sulfide content. While the oxidation of sulfide and subsequent generation of acidic pore water can weaken the host rock, the geology and lithology of the host rock must also be considered when making such comparisons or predicting future stability.

Several factors at GSM indicate that physical or chemical weathering would not likely become a factor in highwall stability, as discussed in Section 3.2.2.3. Field and petrographic observations reveal that beyond a thin surface rind (less than 1 mm) of chemical weathering, the interior of the rocks is very fresh with no signs of incipient weathering (Telesto, 2003d). This thin rind can be seen on the rocks exposed to the atmosphere on the pit highwall as well as along natural and conventional blast induced fractures in the pit highwall. A disturbed rock zone caused by conventional blasting and mining can extend several feet to tens of feet into the pit highwall (Gallagher, 2003a; Paul Buckley, GSM, personal communication, 2003). Blast

induced fracturing on the pit highwall may increase physical weathering, but has a limited effect on chemical weathering. Blast induced fractures and the near-surface consumption of oxygen combine to limit the expected extent of chemical weathering. The geotechnical testing of existing mine material indicates an acceptable factor of safety and the data summarized above suggest that future physical and chemical weathering at GSM would not compromise overall highwall stability.

Although a direct analogy between the cause of weathering of the highwall and waste rock exists, a direct correlation between highwall weathering and weathering of the waste rock cannot be inferred (Telesto, 2003c). Waste rock in the dump complexes has weathered at a rapid rate (Herasymuik, 1996). On the highwall, physical weathering is minimized because the rock is left relatively intact after mining. In a few places in the pit where conventional blasting has caused more damage to the highwall, mostly along existing geologic structures, physical weathering has increased and resulted in localized failures. Because the waste rock has undergone a large amount of handling, such as blasting, loading, hauling, dumping, and spreading, more surface area has been created and it is more susceptible to physical and chemical weathering. Larger rock fragments are placed within the dump and, in a relatively short period of time, break down into smaller particle sizes. Because most of the waste rock is either Mineral Hill breccia or from the zone adjacent to the breccia, it generally contains more sulfides than the rock remaining in the highwalls. The oxidation of the larger amount of pyrite in the waste rock dump complexes has accelerated the break down of the acidic rock. This accelerated chemical weathering has not been as pronounced in the pit rock on highwalls or on benches, which have had less physical damage. Thus, the lack of weathering observed on the highwall indicates that the highwall rock weathering rate is not directly correlated to waste rock weathering (Telesto, 2003c).

The 1998 ROD concluded that the highwall would be structurally stable under the No Pit Pond Alternative. Some raveling, talus formation, and limited sloughing of the highwall can be expected over the long term after mine closure. These occurrences would lead to increased stability of the highwall with minimal impact on the environment outside the pit area.

Under the modified No Pit Pond Alternative in this SEIS, the pit bottom would be deepened from 4,650 feet to 4,525 feet as part of Stage 5B. The effect of deepening the pit on highwall stability was evaluated and found to be minimal (Telesto, 2003d). The pit highwall angles, bench widths, and slope angles between benches would be left generally as shown in Figure 2-3. The bottom of the pit would be filled with 100 feet of crusher reject from 4,525 feet to 4,625 feet, reducing the maximum highwall height from 1,875 to 1,775 feet (Figure 2-3). The properties of the crusher reject material are described in detail in the groundwater effluent management system, Section 4.2.1.5.1. Wells would be installed and water would be pumped to prevent a pond from forming. As the groundwater levels surrounding the pit are drawn down during mining and maintained following mining (HSI, 2003), the pit highwall would become more stable overall. This is because the fluid pressures within the rock mass,

which act to destabilize the highwall, would be reduced (Telesto, 2003d). Small localized seeps would continue, especially along the Corridor Fault and other wet areas, largely in response to precipitation events (Gallagher, 2003b). These areas would remain locally unstable and are susceptible to additional chemical and physical weathering and raveling over time.

In summary, under the No Pit Pond Alternative in the 1997 Draft EIS, it would be expected that some portions of the pit highwall would be subject to raveling, talus formation, erosion, and limited sloughing, thus locally altering the configuration of some of the pit highwall. In particular, sloughing may be expected along the northwest area of the pit, where the orientation of existing faults renders the highwall less stable. As sloughing occurs, however, the overall stability of the pit highwall would be expected to increase over the long term as the rock materials achieve a more stable configuration. The combined effect of potential ground movement over time is anticipated to have negligible environmental consequences outside the pit area, but would impact access, maintenance, and dewatering system operation (Telesto, 2003d).

Under the No Pit Pond Alternative in the 1997 Draft EIS, 100 feet of backfill would have been placed to raise the pit bottom from 4,700 feet to 4,800 feet. The volume of backfill needed was estimated to be up to 500,000 cubic yards (750,000 tons) (1997 Draft EIS, Chapter II, Section II.B.6.b; 1998 ROD). The backfill would have created a working surface of 7.4 acres. In this SEIS, 111,000 cubic yards (167,000 tons) of crusher reject would be placed to raise the pit bottom from 4,525 feet to 4,625 feet. This would create a flat, dry working surface of 1.3 acres.

Due to the concerns over potential small-scale failures, a plan for monitoring and mitigation of slope movement of the pit highwall would be developed and implemented after closure. Survey prisms, which are currently used to ensure safe mining operations, would continue to be used to monitor ground movement in susceptible areas after closure. A plan concerning entry into the pit after a storm event or after long periods of absence would also be developed. These plans would help ensure workers' safety and provide a mechanism to maintain pit access.

Another potential cause of failure is surface water runoff from precipitation events. After closure, this potential would be minimized by storm water controls that would prevent an estimated 99 percent of storm water from entering the pit (Telesto, 2003a). This would be accomplished after final slopes are created and before mining is completed if possible. Otherwise, localized failures may occur increasing the amount of rock that ravels and sloughs onto safety benches and the pit bottom.

The term "risk" encompasses the concepts of both the likelihood of failure and the severity of the expected consequences if such events were to occur. An analysis considers both the risk of a failure and uncertainty in estimating the risk. This SEIS explains both the risk and uncertainties in the analyses that were conducted.

Likelihood categories are generally qualitative. However, the use of numerical probability ranges to define the frequency of site specific events can provide additional guidance. Likelihood of failure was evaluated qualitatively for this analysis. In order to assess the impact or consequence of any potential failure on a system, potential receptors must be identified and characterized. Receptors vary at and within each mine site. Key receptors can include human health and safety; the environment; corporate reputation; community relations; government relations; legal consequences; and costs. Likelihood of occurrence and consequence are then evaluated to determine risk.

In the highwall stability analysis for each alternative, the agencies made assumptions of material quantities that could slough or fail over time. Although these quantities are not based on empirical data, as such data do not exist, they do provide a comparative analysis of alternatives. The assumed quantities of material may be subjective; however, the likelihood of such a failure occurring and the consequences of that failure do not change and, therefore, the risk does not change. Technical information prepared for this SEIS was used in evaluating the risk involved with highwall stability issues.

Sloughing of the pit highwall was not as much of a concern in the 1997 Draft EIS because the working area would have been 7.4 acres in size, providing room for raveling and sloughing highwall rock, and the predicted failures would have been small over time. The 1997 Draft EIS and this SEIS analysis concluded that the risk of a large failure was low over time.

To address risk and uncertainty in this SEIS, the agencies have assumed failures would occur over time similar to those that have occurred during operations, as listed in Section 4.2.1.2.1. The agencies have assumed 100,000 cubic yards (150,000 tons) of highwall rock would ravel over time, especially on the northwest highwall, eventually covering the 5,700-foot elevation safety bench and rolling to the bottom of the pit. In addition, the agencies assumed another 100,000 cubic yards would slough into the pit from the northwest portion of the highwall, which would eliminate access to the bottom of the pit, bury the dewatering system, and cover the 1.3-acre working surface. To restabilize the pit, GSM would have to reestablish the safety bench at the 5,700-foot elevation, reopen the access road into the pit, haul more backfill into the pit to create a new larger working surface, and reestablish safety berms and the dewatering system wells. The agencies have assumed this could occur more than once over the long term. The agencies have assumed that, over time, highwall rock and crusher reject in the bottom of the pit would be 200 feet deep and total 600,000 cubic yards (900,000 tons).

As a contingency, if the dewatering system was destroyed or became inaccessible, the agencies would require GSM to submit a plan for development, maintenance, and monitoring of a portal at a suitable elevation to allow access to the underground workings, so that dewatering would still be possible using the underground sump.

Even with these failures, there would be minimal impacts outside of the pit from periodic pit failures over the long term.

4.2.1.2.3 Pit Highwall Maintenance Requirements

As discussed under Pit Highwall Stability above, small-scale highwall instability would continue after closure under the No Pit Pond Alternative, which would affect pit highwall maintenance. Pit highwall maintenance requirements would be higher for alternatives that leave the pit open, such as the No Pit Pond and Underground Sump alternatives.

Highwall safety benches, especially the 5,700-foot safety bench, that are present during mining, would remain in most areas and would catch most rock that ravels after closure. The pit haul road would have to be maintained for access. The highwall safety benches would have to be maintained to protect workers in the pit. The crest of the pit would need to be monitored regularly for tension cracks to identify when movement is occurring and to ensure storm water run-on does not enter the pit.

The agencies have assumed that safety benches would be compromised over time and that as much as 200,000 cubic yards (300,000 tons) of rock would ravel and slough to the bottom of the pit. This would require periodic maintenance to reestablish the 5,700-foot safety bench above the pit floor, clear the access road, haul more backfill to create a new larger working surface, and move rock to reestablish safety berms on the working surface. The agencies have assumed this could occur more than once over the long term, as described in Section 4.2.1.2.2.

Technical reviews, additional analyses (Brawner, 2005; Golder, 2005), and the conclusions in the Draft SEIS confirm that the pit highwall stability conclusions reached in the 1997 Draft EIS remain valid with respect to overall slope stability. Additional analyses of pit highwall raveling and of wedge failure indicated that there is little potential for structurally controlled failures with the exception of the existing failures in the west and northwest walls (Brawner, 2005; Golder, 2005).

Other operational measures that GSM would implement to stabilize the pit in preparation for this reclamation alternative would include the following (Brawner, 2005; Golder, 2005):

- A 100-foot-wide safety bench would be left at the 5,700-foot elevation. Narrower catch benches spaced every 100 vertical feet would also be left to catch rock fall that would occur after mining is completed.
- Wire mesh would be installed over some sections of the west wall failure to mitigate rock fall hazards. Two dowels have been placed to secure a sandstone block. Additional bolts or dowels would be installed. Reinforcement considered critical in the long-term would include appropriate corrosion protection.

- Bench face angles would be reduced in the Lone Eagle Fault Zone, and bench crests would be reduced in local areas of the west highwall in the footwall of the Corridor Fault Zone and along the south wall where there are north-dipping geologic bedding structures.
- Potentially unstable slabs or wedges would be mined out.
- Horizontal drains would be installed around the pit perimeter to reduce water pressure in the pit highwall if seepage is encountered in the lower 300 feet of the Stage 5B pit.
- Drainage interception ditches would be constructed around the open pit to minimize surface water flowing over pit slopes.

Although rock mass stability analyses indicate adequate factors of safety for overall highwall slopes, a long-term stability monitoring and maintenance program would be required for the No Pit Pond and Underground Sump alternatives. Monitoring would concentrate on failure areas on the west and upper northwest highwall areas. The proposed program would include the following (Brawner, 2005; Golder, 2005):

- Regular inspection of the pit by a rock mechanics professional;
- Installation of piezometers to periodically monitor pore water pressures;
- Monitoring of areas where failures have occurred;
- Installation of 8-10 global positioning system monuments on selected locations to monitor movement;
- Monitoring of water levels in wells;
- Restricting access to the pit during and shortly after rainfall events, rapid thaws, and seismic events; and,
- Cleaning catch benches as needed.

4.2.1.3 Backfill

Large open pits have become a common part of modern mining operations. Although pit backfilling has not been required as part of MMRA and/or BLM's Surface Management Regulations, several mines in Montana have used backfilling to some extent. In Montana, some of the larger examples include:

- Montana Resources in Butte
- Beal Mountain south of Gregson
- Basin Creek between Helena and Basin
- Zortman and Landusky in the Little Rockies
- CR Kendall near Hilger
- Treasure Mine northeast of Dillon
- Yellowstone Mine south of Cameron

Some pits have been backfilled in Montana by mining companies as part of regular mining operations when multiple pits were developed at one mining complex and it was a shorter haul distance to deposit waste rock. Some examples include:

- Montana Resources: The East Continental Pit was backfilled as part of the East Waste Rock Dump construction. The Pittsmont Dump was placed in the Continental Pit. The Pittsmont Dump may have to be removed again in future mining operations as ore still remains in the pit.

- Beal Mountain: The Main Beal Pit was partially backfilled during mining of the South Beal deposit. The pit was backfilled above the level of the water table with South Beal waste rock, and the high-sulfide rock in the lower Main Beal Pit highwall was covered with South Beal waste rock and revegetated. The quality of the pit discharge slightly exceeds water quality standards. The US Forest Service is monitoring the water discharging from the Main Beal Pit for water quality changes over time.

- Basin Creek: The Columbia Pit was backfilled during waste rock dump formation. The Paupers Pit was backfilled with the waste rock dump because of waste rock dump stability problems. The backfill is in the water table. The quality of the pit water, as well as local springs in the mineralized area, does not comply with water quality standards. DEQ and EPA are monitoring local springs in the area for potential increased water quality problems from backfilling the pit.

- Zortman and Landusky: Part of the Landusky Gold Bug Pit above the water table was backfilled during mining of adjacent pits.

- CR Kendall: The Haul Road Pit and the South Horseshoe Pit were backfilled with waste rock after the ore was mined out. Also, partial backfill of the Muleshoe and Kendall pits occurred during later mining of adjacent pits. The backfill material is above the water table.

- Yellowstone Mine: The South Main Pit and North Forty Pit were backfilled after the ore was removed and other pits were expanded. There is no water in the pit backfill material.

Other pits have been backfilled as part of reclamation conducted by the agencies after bankruptcy or settlement agreements. Some examples include:

- Zortman and Landusky: At Zortman, most of the pits have been backfilled to a free-draining condition to limit water needing treatment by diverting surface water off the backfill. The water table is beneath the bottom of the Zortman pits. At Landusky, some of the pits were backfilled to a free-draining condition. The water table level is in the backfilled portion of the Landusky pits. Most of the water is drained out of the Landusky pits backfill by an artesian well and the August Tunnel and is collected and treated. The volume of backfill placed into the Landusky Pits was limited by the quantity of non-sulfide waste rock available, plus the goal of capping the backfill as quickly as possible in order to minimize its exposure to precipitation.

Despite the existence of underground tunnels and major shear zones beneath the Landusky pits, contaminant pathways could not be predicted with enough certainty to rely on pumping and treating to contain leachate from the backfill. Instead, restrictions were placed on backfill material quality.

- CR Kendall: Some pits are being considered for backfill based on water issues related to the location of the waste rock dumps in drainage bottoms. The water table is below the bottom of the pits. The feasibility of placing waste rock in the pit would have to be weighed against the advantages of removing it from the drainage bottoms. Water would be difficult to collect in the pits.

4.2.1.3.1 Pit Backfill Analog Study

A survey of existing open pit metal mines in the U.S., Canada and Sweden was performed to provide an "analog" to assist in evaluation of pit closure for those alternatives with partial pit backfill (Kuzel, 2003; Gallagher, 2003c). Information regarding other pit backfill projects was assembled utilizing many of the backfilled mines presented in the 1995 Mine Environment Neutral Drainage Program report (SENES, 1995). A total of 19 mines with potential pit backfills or pit lakes were initially contacted in 2003 (Kuzel, 2003). Information was gathered through telephone interviews and responses to written survey questions. Subsequently, emphasis was placed on mines with similar geology and climate, and that had a history of water quality monitoring (Gallagher, 2003c).

After screening the potential sites, three mines were chosen for more detailed evaluation, the San Luis Mine in southern Colorado, Richmond Hill Mine in the Black Hills of South Dakota, and the underground workings and Berkeley Pit at Butte, Montana (Gallagher, 2003c). None of the sites was a reasonable analog to the GSM pit backfill scenario. For instance, the San Luis Pit has very different geology, the Richmond Hill backfilled pit is unsaturated, the Butte underground consists of saturated underground mine workings rather than a backfilled pit, and the Berkeley Pit is not backfilled.

No backfilled pit of comparable size was found. The San Luis Pit was approximately 100 acres and 140 feet deep. The Richmond Hill Pit was 35 acres and 150 feet deep. A summary of the pit characteristics and findings of the survey is provided in Table 4-1 (Gallagher, 2003c, as updated by the agencies).

Table 4 - 1. Summary of information for Golden Sunlight, San Luis, Richmond Hill and Butte mines[1]

	Partial Pit Backfill With In-Pit Collection Alternative - GSM	San Luis, Colorado	Richmond Hill, South Dakota	Berkeley Pit, Montana	Butte Underground, Montana
Pit size (acres)	218	~100	35	~ 675[2]	About 10,000[3] miles of tunnels
Pit depth (feet)	1,875	140	150	1,780[2]	Up to 1 mile deep
Backfill amount (tons)	50 million	5.78 million	3.5 million	N/A; pit lake ~900 feet deep	10-25 percent gob[4] and slimes
Backfill depth (feet)	775-875	140	<150	None except sloughing	N/A
Geology	Tertiary breccia pipe in Precambrian metasediments	Precambrian biotite-amphibole-quartzo-feldspathic gneiss	Tertiary breccia pipe in Precambrian amphibolites.	Quartz monzonite, quartz, energite mineralization	Similar to Berkeley Pit with some unique mineralogy within individual mines
% /Type sulfide	Variable-1997 Draft EIS 0.5 to 2 percent pyrite in backfill	Range 0.49 to 5.43 percent as sulfur	Variable – average 1 percent – oxidized / 0-20 percent unoxidized zone pyrite and marcasite	Abundant pyrite, chalcopyrite, enargite	Abundant pyrite, chalcopyrite, bornite, chalcocite, covellite, digenite
Period of Water Quality Date	2002-2003 from in-pit sump	1997 to present	Pit backfilled – 1995; data through 2003	~20 years	~20 years
Saturated/ Unsaturated	< 100 feet Saturated/675-775 feet unsaturated	Both	Unsaturated	Saturated	Saturated (90 percent)
Geochemical testing	See Telesto, 2003c	Sequential Leach and humidity cell	ABA, NAG, whole rock, humidity cells, column leach test, mineralogy	N/A	N/A

Predictions	Poor quality leachate would form (Table 4-5)	Water quality degradation would not be an issue in backfilled pit	No water level rebound; no water quality impacts	Pit water level predictions; no change in water quality over time assumed in RI/FS[5]; water quality for some constituents has improved over time (Maest, 2003)	Water level predictions; no change in water quality over time assumed in RI/FS[5]
Discharge from pit	Assumed less than 10% of flow (1.5 gpm)	Seeps developed at contact of Rio Seco alluvium and pit backfill material	Seeps formed down gradient from unsaturated pit	Poor quality pit lake water (hydrologic sink has not reached critical water level); at that point 6.08 million gal/day would be pumped from the pit and treated[2]	Improvements in water quality after initial flooding, stable or declines in past several years. All discharges report to the Berkeley Pit hydrologic sink.

[1] From Gallagher, 2003c modified by the agencies.
[2] Canonie, 1993.
[3] Duaime et al., 2004.
[4] Gob consists of low-grade ore/high-grade waste rock left in the mine tunnels during mining. The material was deemed uneconomic and therefore, was not brought to the surface. Montana Bureau of Mines and Geology personnel noted the tunnels contained much less than 50 percent gob and more likely 10 to 25 percent, although exact percentage fill is unknown.
[5] RI/FS – Superfund Remedial Investigation/Feasibility Study.

4.2.1.3.2 Backfill Maintenance Requirements

Settling in the 100 feet of crusher reject used for the sump would be 10 feet after a few years, as discussed in Section 4.2.1.5.2 (Telesto, personal communication, September 2004). Some additional settling could occur over the long term after large storm events or during snow melt, if the water level rose in the crusher reject for a short time before it could be pumped back down. Continued chemical weathering of the crusher reject over time would also produce some settling as this acidic rock weathers into smaller-sized particles from pyrite oxidation making it harder to dewater effectively.

Safety benches would have to be maintained to protect workers. Rock raveling off the highwall and escaping the safety benches and/or berms would have to be removed to maintain access. Periodic grading and dozing of the surface of the backfill may be needed to remove rocks that have raveled and sloughed. For information on soil cover maintenance requirements on the backfill working surface, see Soil Cover Section 4.2.1.7.

The agencies have assumed 100,000 cubic yards (150,000 tons) of rock would ravel to the pit bottom over time. As discussed in Section 4.2.1.2.2, the agencies have assumed a 100,000-cubic-yard failure under the No Pit Pond Alternative, which could eliminate access to the bottom of the pit and destroy the dewatering system. If this were to occur, the water table would begin to rebound in the pit backfill. GSM would have to reestablish the safety bench, access, and the safety berm, and haul additional backfill into the pit to stabilize the material on the pit bottom and reestablish a safe, flat, larger working surface. Wells would have to be redrilled. The agencies have assumed this type of failure could occur more than once over the long term.

4.2.1.4 Underground Workings

4.2.1.4.1 Impacts to Pit Facilities Due to Subsidence Related to Underground Mining

The first phase of underground mining ceased in January 2004. The permit for the underground mine indicated that portions of the underground mine that break through into the pit or that might pose a hazard to work in the pit would be backfilled. As of June 2004, no underground workings have been backfilled. The current mine plan for the Stage 5B pit includes mining to a safe distance from the underground stopes as determined by the GSM engineering department, backfilling the stopes, and then mining through the stopes. The stopes would be backfilled by blasting a raise into the stope and backfilling with rock material from the surface. At the end of the open pit mining, the location of the "C" stope would be evaluated to determine if it must be backfilled. However, this stope should be more than 100 feet from the pit highwall. The remaining

stopes would be mined out by the Stage 5B pit (Figure 2-2). Surface subsidence above the underground workings that are not backfilled would not be expected to occur (GSM, 2002a). During underground mining, rock stability was continuously monitored and this monitoring information has not indicated any potential for subsidence or failure.

Based on the rock properties, design of the underground mine, monitoring and maintenance activities, and observations made during mining, subsidence of the underground workings is not expected to be a major problem. No monitoring of the underground workings is proposed for the No Pit Pond Alternative.

Localized failures of overhead rock over time, especially in the stopes, could result in subsidence, especially in seep and fault areas where chemical weathering would be increased. This subsidence could cause the 100 feet of crusher reject to settle affecting the dewatering wells in the backfill. The agencies would require GSM to replace wells that failed for any reason.

4.2.1.5 Groundwater/Effluent Management System

The No Pit Pond Alternative would maintain the pit as a hydrologic sink, keeping the groundwater level in the pit as close as possible to the final pit bottom at the 4,525-foot elevation. Regular pumping would prevent water quality from degrading further over time in the acidic crusher reject. Precipitation, surface runoff, and groundwater seeps that drain into the pit would be removed by two to three dewatering wells and routed to the water treatment plant (GSM, 2002a).

4.2.1.5.1 Operation Requirements (Number of Wells)

The dewatering system would consist of two to three wells constructed through the 100 feet of crusher reject used for pit backfill to the bedrock contact. The permeability of the crusher reject is expected to be in the range of $1x10^{-3}$ cm/sec (Telesto, 2003e). Boreholes would be 10 to 12 inches in diameter and would be lined with 6-inch diameter Schedule 80 PVC casing. The bottom of the casing would be slotted. A stainless steel submersible pump equipped with electronic sensors to maintain optimum drawdown would be installed in each well. The water would be routed by pipeline to the water treatment plant prior to being discharged back into the ground, away from the pit area, in percolation ponds, LAD areas, or by other approved methods.

In addition, GSM would install horizontal drains in the highwall and incorporate these into the dewatering system as required to maintain safe operations. For existing operations, drains are located based on observation. The intent is to eliminate the potential for hydrostatic pressure in the highwall in areas of active mining. At closure, areas of the pit would be evaluated. If areas of the highwall were determined to be susceptible to hydrostatic pressure, additional hydrogeologic evaluations could be necessary to determine if drains were

necessary. GSM personnel would conduct this evaluation, unless additional expertise was deemed necessary. Drains have been used by GSM in areas of active mining (GSM, 2002a). The discharge would drain by gravity to the backfill sump, from which it would be pumped by the wells and transferred by pipeline to the water treatment plant. Dewatering also takes place from two existing vertical highwall wells (PW-48 and PW-49). The highwall wells are located on a pit bench at the 5,800-foot elevation. The wells are located at an elevation above the Stage 5B pit expansion, and therefore will not be affected during mining. Some road maintenance has been required in the past to remove rocks that have raveled down onto the bench. However, walking access for monitoring activities has never been lost. These wells would continue as required to release pore pressures in the open pit highwall to minimize the potential for highwall failure during Stage 5B mining. Figure 3-5 shows the location of the dewatering wells.

The feasibility of pumping from 100 feet of backfill was not investigated in the 1997 Draft EIS. The No Pit Pond Alternative calls for backfilling the bottom 100 feet of the pit with approximately 111,000 cubic yards (167,000 tons) of crusher reject from the 4,525 to 4,625-foot elevation. The crusher reject is expected to have the durability and uniformity to provide an adequate permeability over time. The permeability was estimated at $1x10^{-3}$ cm/sec (Telesto, 2003e). East Waste Rock Dump Complex waste rock has been tested and the permeability is $1x10^{-3}$ to $1x10^{-5}$ cm/sec (Telesto, 2003d). The reduction in permeability is due to chemical weathering of the waste rock.

The acidic water in the backfill would cause corrosion of dewatering system components, as discussed below in Section 4.2.1.5.2. Redundancy would be necessary to ensure continuing operation of the dewatering system. One well can easily handle the anticipated pumping rate of 25 to 27 gpm. While mining Stage 5A, GSM pumped all of the pit inflow, generally from 10 to 30 gpm, from a sump at least 100 feet deep into waste rock in the pit bottom utilizing a single cased well. In order to ensure continuous operation, one additional standby well would be required. A third well would only be required if the one operating well and one standby well were to fail.

4.2.1.5.2 Maintenance of Capture Points

Under the No-Pit Pond Alternative, two to three wells would be used to remove acidic water from 100 feet of crusher reject. Several problems could affect maintenance of these wells over time, including highwall raveling and sloughing, settling, corrosion, scaling, and potential biofouling. The agencies are concerned with maintaining the ability to dewater the backfill, prevent an acidic pond from forming in the bottom of the pit, and prevent discharges from the pit.

As described in Section 4.2.1.2.2, gradual raveling of highwall rock and occasional failures over time would cover the safety bench at the 5,700-foot elevation and would allow some highwall rock to reach the pit bottom. Some of

the rock may overtop the safety berm and make it to the pit floor flat working surface and dewatering system. Damage to the wellheads, monitoring equipment, power lines, pump stations, and/or to the pipelines routing water out of the pit along the access road to the water treatment plant would occur.

The physical integrity of dewatering wells could be threatened due to settlement and consolidation of the 100 feet of pit backfill. Settlement of the backfill could impair the integrity of the well casings due to buckling, separation, or shearing. It could also cause bends or kinks in the casings that, although less severe, may prevent or impair access to the pump for maintenance and operations. About 70 percent of this settlement, 7 feet, would occur during the backfill operation and 30 percent, 3 feet, over a longer period after backfilling is complete (Telesto, personal communication, September 2004). This could affect well casing integrity and require replacement over time.

The corrosion potential of projected pit water quality was evaluated by Telesto (2003e). Three sources of water quality data were evaluated: pit seeps, 2002 to 2003 pit sump water, and the Midas Spring discharge out of the northeastern part of the East Waste Rock Dump Complex. The average pH for these three sources was 3.6, 3.4 and 2.3, respectively. The Langelier Saturation Index (LSI), which is widely applied in the estimation of a water's potential to either corrode or scale equipment, was utilized to evaluate corrosion potential (Grove, 1993). The LSI rating scale ranges from -5 for "severe corrosion", to 0 for "balanced water", to +5 for "severe scaling". The lower and upper 90-percent confidence intervals for the pit seepage and pit sump waters produced LSIs of -7 to -4. The average Midas Spring water quality had a LSI of -7.3.

The corrosion study concluded that the expected water quality from East Waste Rock Dump Complex waste rock would be more corrosive than water quality in the pit sump measured from 2002 to 2003. The crusher reject used in the No Pit Pond Alternative would be similar. The expected LSI (-5 or less) would result in severe corrosion potential if water is not pretreated. Under the No Pit Pond Alternative, no pretreatment is proposed prior to pumping from the pit. Stainless steel pumps would be used, but, because of the low LSI of the backfill water, their life expectancy would be shorter than that of dewatering pumps used in 2002 to 2003 pit backfill dewatering operations. Steel well casings were predicted to have a lifespan of only a few months (Telesto, 2003e). Stainless steel casings would corrode over time as well, although they would last longer.

Acidic water could produce iron hydroxide scaling as well as bacterial biomass, *i.e.*, biofouling. This scaling would plug pumps, pipes, slotted casings, etc. and would shorten the functional life of wells. The low LSI rating for predicted pit water quality indicates scaling would not be a problem. GSM has reported limited problems with scaling over the life of the mine (GSM Annual Reports).

Standard corrosion potential modeling using LSI does not include biofouling potential. Problems from biofouling of wells and pumping equipment are expected to be minimal due to the low pH of the water. Biofouling becomes more of a problem as the pH increases above 4.5 (Cullimore, 1996). The basis for this prediction comes principally from experience at GSM and review of the literature on causes, prevention, and limiting factors (Telesto, 2004).

4.2.1.5.2.1 GSM Experience with Dewatering

Pit reclamation alternatives being considered for pit closure at GSM include long-term pumping of water from wells of various depths. In some alternatives, wells would be installed through the backfill to the bedrock contact and routinely pumped to maintain the water level in the backfilled pit at an acceptable minimum elevation. In another alternative, additional wells would be installed and operated down gradient of the pit. These wells would be similar to existing pumpback wells south of the GSM facilities. For the SEIS, Telesto performed several feasibility analyses regarding well performance based upon projected water quality of the backfill (Telesto, 2003e). The potential effects of biofouling on well performance were also evaluated (Telesto, 2004).

GSM has operated dewatering systems at the mine for a number of years. These systems have been utilized in different scenarios. The following discusses the potential problems that can occur with pumping wells, including corrosion, scaling, and biofouling, and summarizes GSM's experience in operating dewatering systems.

4.2.1.5.2.1.1 Background

Although several factors can affect well performance, the items of greatest concern in the SEIS are settling and corrosion. Depending on pH, scaling and biofouling could be problems. GSM has dealt with each problem in different areas of the site during pumping activities.

The physical integrity of dewatering wells can be threatened due to settlement and consolidation of the material where the well is installed. Settlement can impair the integrity of the well casings due to separation, buckling, or shearing. It can also cause bends or kinks in the casings that may prevent or impair access to pumps for maintenance and operations.

Corrosion can limit the useful life of wells in a number of ways, including enlargement of screen slots, followed by sand pumping; reduction in strength, followed by failure of well screen or casing; deposition of corrosion products, blocking screen openings; and inflow of lower quality water caused by corrosion of the casing (Driscoll, 1986). Corrosion can result from chemical or electrochemical processes. Plastic or stainless steel is typically utilized to reduce corrosion problems in wells.

Scaling can be a major cause of well failure. Water quality chiefly determines the occurrence of scaling (Driscoll, 1995). The kind and amount of dissolved minerals and gasses in water determine their tendency to deposit mineral matter as scale. During pumping, velocity induced pressure changes can disturb the chemical equilibrium of the groundwater and result in the deposition of soluble iron and manganese hydroxides. A coating of iron hydroxide can build up, particularly if pumping is started and stopped intermittently.

Biofouling by iron-fixing bacteria is a common problem in wells worldwide. In general, iron-fixing bacteria gain energy by enzymatically catalyzing the oxidation of ferrous iron to ferric iron. The bacteria then use the energy gained from the oxidation process to reproduce, sometimes exponentially, resulting in a slime-like coating that may contain ferric hydroxides, ferric oxy-hydroxides, and hydrated ferric hydroxides. The slime precipitate can cause plugging of well screens and sand packs, rendering a well practically useless in a short time period. The introduction of iron-fixing bacteria into a well is not always certain. The bacteria may exist in-situ before the well is completed, or they may be carried in on drilling equipment or in drilling fluids that were exposed to the atmosphere prior to drilling. Regardless, iron-fixing bacteria are prevalent in the environment (Driscoll, 1995). Some species prefer circumneutral pH ranges, while others do well in low pH conditions.

GSM has operated dewatering systems in different scenarios. GSM has operated wells or dewatering systems in the pit highwall, the pit bottom, the underground workings, down gradient of the tailings impoundments, the Midas Spring area, and in waste rock dumps. The following discusses experience in operating each of these systems.

4.2.1.5.2.1.2 Highwall Dewatering Wells

Two vertical highwall wells (PW-48 and PW-49) within the pit have been regularly pumped to intercept groundwater from the Corridor Fault area before it enters the pit. The wells are located on the 5,800-foot-elevation bench of the north highwall. PW-48 was completed to 925 feet (perforated interval 851-925 feet); and PW-49 was completed to 455 feet (perforated interval 415-455 feet). PW-48 and PW-49 were constructed in July 1997, but were not regularly pumped until October 1999. These wells produce a combined flow of approximately 18.2 gpm (Telesto, 2006).

Water quality in PW-49 is typically better than pit water, indicating the well is mostly intercepting intermediate groundwater. However, during high precipitation events, the water quality declines. During 2003, the pH of well PW-49 remained above 5. However, the water is acidic and has high levels of metals, such as iron and manganese.

Some maintenance is required for operating these wells. Flowmeters plug quickly and have to be maintained on a regular basis. Flowmeters are the largest maintenance item related to the highwall wells, as they become plugged with iron and other scale. This most likely is due to iron scale forming on the well screens and casing and then being pumped from the well. Because these wells are not vital to the actual dewatering operation, temporary down time is not typically an issue. The flow rates in these wells have declined over time. The pump had to be pulled from well PW-49 in April 2006. The pump was pulled, the well screen was brushed, and the pump was replaced. However, this did not improve production from the well. Due to the flow significantly decreasing in late 2006, the pump and well casing were pulled out. The bottom 35 feet of the well screen was filled with iron scale, and the pump was ruined. Therefore, it can be shown that scaling can affect well efficiency to a large degree in this system (Shannon Dunlap, personal communication, 2007).

As these two wells are constructed in the bedrock in the pit highwall and the pH of the water is about 5.0, their operation is not indicative of what would be expected to occur in wells installed in backfill material with a pH ranging from 3.0 to 4.3, but could be indicative of potential wells installed in bedrock down gradient of the pit.

4.2.1.5.2.1.3 Pit Dewatering Well

The pit dewatering system used in 2002 to 2003 consisted of a 118-foot-deep dewatering well in about 150 feet of backfill, a 15 horsepower (hp) stainless steel submersible pump, booster station, and associated piping and storage structures in the pit. The dewatering well was constructed in a combination of crusher reject and waste rock previously pushed into the bottom of the pit from higher benches. The well was a HDPE pipe with slots. Water was allowed to collect in the backfill material, and the well was pumped periodically to keep the water down to an acceptable level for underground and open pit mining activities, below the pit bottom. Piping consisted of HDPE and PVC.

The average pH of the water pumped from the pit during 2002-2003 was 3.6. This well was utilized for a period of approximately 10 months.

The largest maintenance issues involved deterioration of PVC pipe sections, float switches, and centrifugal pumps at the booster station due to the low pH of the water. In addition, plastic parts occasionally were affected by heat due to the pumping scheme. When dewatering was occurring on a continuous basis, approximately 20-30 hours per week were spent on the dewatering system maintenance, which included the pit dewatering well and highwall wells. Stainless steel parts did not deteriorate during the active life of this well. No biofouling problems were identified when the pump was removed and the well was mined out. During the 10 months, pumping rates were not reduced from either well screen or pump intake clogging. When the pump was removed, it had

no scale or slime growth on it. In addition to low pH water, another key factor for preventing or minimizing biofouling is to limit the aerobic/anaerobic interface near well screens and pump intakes. By proper well design and pump operation, the water level can be maintained above the screens and water entry velocities kept low, which may limit biofouling. As the hydrology of the system becomes more complicated, this becomes more difficult to accomplish.

Problems were encountered with the lowest portion of the well silting in. This was most likely due to the slot size and the fact that the well was not installed with a gravel pack. The pump was periodically raised in the well casing to alleviate this issue.

Well operating issues that occurred during this time would be expected to recur under the No Pit Pond Alternative. Due to the weathered acidic waste rock being placed in the pit and depth of backfill in the Partial Pit Backfill With In-Pit Collection Alternative, the issues could be compounded. Given the likelihood of elevated iron concentrations in the water to be pumped from the potential backfill, and the "omni-presence" of iron-fixing bacteria, biofouling of backfill wells is possible if the pH rises. Treatment of biologically fouled wells typically includes some type of oxidant (*e.g.*, chlorine, bromine) to break down the cell walls of the bacteria. Oxidants also can precipitate oxides of many metals. Given the high metals concentrations projected in the backfill, the introduction of oxidants could create other problems, such as lower pH in the well and chemical precipitation that could induce further well fouling. Thus, the ability to treat a biologically fouled well may be impaired by the physical and chemical conditions that would be present.

In the event biofouling occurred as determined by production loss or pump/well inspection, there are a number of rehabilitative processes, which could be tried short of constructing new wells. The best would be to high-pressure water jet the screen with subsequent well flushing. Another would be to chemically oxidize any bacterial growth. New methods, which could also be tried, use a combination of treatments such as dispersants, pH modifiers, and disinfecting agents. Biofouling is not expected to be a major problem because of the low pH of the pit water. Biofouling has not been a problem at GSM during operations. Therefore, biofouling is not expected to be a problem in water management after mining.

4.2.1.5.2.1.4 Underground Dewatering

The pit dewatering system used during underground mining from July 2002 to January 2004 consisted of a sump in the underground workings to drain and collect pit water. Water in the pit flowed into the underground workings through drill holes connecting the bottom of the pit with the underground workings. The underground mine had a sump with an approximate 500,000-gallon capacity at an elevation of approximately 4,650 feet. Any water that collected in other areas

of the underground workings was pumped to this sump. Water was pumped from the underground sump through a 3-inch HDPE line to the 4,700-foot booster station. From the 4,700-foot booster station, water was pumped to the 4,850-foot booster station, and then to the 5,000-foot bench booster station through 4-inch HDPE lines. Finally, the water was pumped out of the pit from the 5,000-foot bench booster station, through a 4-inch HDPE line, to a lined holding pond below the mill.

In 2003, the pH of the water pumped from the underground workings ranged from 3 to 4.3. The water contained high levels of metals such as iron and manganese. No corrosion problems occurred with the underground dewatering equipment despite predictions based on the LSI rating. Problems were encountered with the booster pump system, as described for the pit dewatering. The quality of water extracted from the underground workings is expected to be similar to that observed for the pit highwall seeps. Based on previous experience, stainless steel pumps and parts may have a reasonable life expectancy.

Following the cessation of underground mining in January 2004, water collected in the underground workings. This water flowed to the underground workings through drill holes connecting the pit bottom with the underground workings. After the cessation of underground mining, no water was removed from the underground workings through June 2006 (Shannon Dunlap, personal communication, 2006).

Pit dewatering issues that occurred during this time would be expected to be similar to the Underground Sump Alternative and not the No Pit Pond Alternative. However, due to the contact time between the water and the pit rock, the ultimate water quality would not be expected to be good (Table 4-5).

4.2.1.5.2.1.5 Groundwater Pumpback Wells

As of the end of 2005, GSM operated 31 pumpback wells south of the tailings impoundments (Shannon Dunlap, GSM, personal communication, 2006) (Figure 3-5). The four Rattlesnake Gulch wells are also pumped regularly above the Buttress Dump. The pumpback wells have been operated since the mid-1980s and early-1990s; the Rattlesnake Gulch wells have been operated since 1998.

The water quality in the pumpback wells is not similar to the pit area water. The Rattlesnake Gulch well water is naturally acidic, although not to the extent of the pit area water.

Operational monitoring of the pumpback wells ensures efficient operation of the active seepage control system. Flow rates, dynamic and static water level measurements, and regular maintenance are key elements to this monitoring. The pumpback well systems have totalizing flowmeters that are normally

checked twice per month to determine monthly average flow rates. Monitoring wells are associated with each group of pumpback wells. GSM inspects all of the operating pumpback wells daily. Lights, which serve as visual indicators, have been installed on each operating well. If operational checks indicate a deviation from normal operation, maintenance personnel are advised immediately. Proper operation of these wells is important; therefore, any required mechanical/electrical inspection or repair work is done as quickly as possible.

The Rattlesnake Gulch wells were originally plumbed with steel and plastic pipe and fittings. Problems initially developed with pumps and plumbing at least every 3 months. The system has been re-plumbed with Schedule 80 PVC and stainless steel. In addition, the flow rates in these wells have decreased. No major repairs have been required for approximately 3 years on the Rattlesnake Gulch wells. The pumpback wells were originally plumbed with steel pipe. Smaller pumps were installed in all of the wells and all of the plumbing converted to Schedule 80 PVC.

Maintenance of the pumpback system is time consuming but routine. Maintenance activities consist primarily of pump replacement, hour meter repairs, and flowmeter repairs. Corrosion, scaling, and biofouling have not been problems recently. Some silting, sanding, and scaling in pumpback wells was noted in 1993 and 1995 (GSM 1993 and 1995 Annual Reports). Approximately three pumps are replaced per year. As the aquifer continues to be dewatered, well yield decreases, and, in some cases, the wells dry up. As the well yield decreases, smaller pumps must be installed in the wells.

The entire pumpback well system was redone in 2001. GSM completely refurbished the east flank pumpback wells and the south pumpback wells, which included a total of 48 wells. The work consisted of setting up on each well, pulling the original column pipe and pump (2-inch steel pipe, 5 to 7 hp pump), blowing debris from the well using compressed air, and cleaning the screen. Once the well was redeveloped, appropriately sized new pumps were placed in the wells. One-inch PVC pipe was used instead of steel for easier maintenance. Equipment required for the project included a pump truck, air compressor, and associated equipment. Daily monitoring of these wells takes approximately 2 hours per day. Approximately 20 hours per month are typically spent on maintenance activities for these 48 wells.

Operating issues similar to these wells could be expected for the Partial Pit Backfill With Downgradient Collection Alternative.

4.2.1.5.2.1.6 Midas Spring

The Midas Spring capture system is located below an area formerly occupied by a small slump and spring. To prevent groundwater from contacting dump material, a portion of the spring area was previously excavated, and a gravel

drain and piping system was constructed in early 1994 to intercept shallow groundwater and lower the potentiometric surface beneath the dump complex. Acidic discharge from the Midas Spring is captured in a series of drains beneath a portion of the East Waste Rock Dump Complex. The drains route the water to a collection tank/pumping system, where it is then pumped via pipeline to the water treatment holding pond in upper Rattlesnake Gulch. This water is then blended with water pumped from the open pit and treated in a lime-precipitation treatment plant located in the mill complex.

The Midas Spring water is poor quality. The Midas Spring was impacted when it was covered with waste rock (in the East Waste Rock Dump Complex) during the early stages of mining at GSM. This spring also has a unique geologic setting in that it is located in an area with structurally controlled high sulfide mineralization, elevated iron, silver, and copper, deep oxidation, and a surface seep influenced by a landslide/debris flow. Therefore, water from the Midas Spring is considered to represent "worst-case" seepage from waste rock dump material.

Stainless steel submersible pumps used to pump water from the Midas Spring to treatment have to be replaced at least every 6 months. There are times when a pump may only last 2 weeks due to failure of pump and motor components, which are not stainless steel. Pumping of solids most likely also affects the life of these pumps. The manifold lines have to be cleaned at times due to solids building up in the line. In addition, sludge that accumulates in the tank has to be removed periodically.

GSM and EPA conducted a research project on the Midas Spring during which the spring was diverted into a lined pond filled with crushed limestone. The limestone became plugged within a year and a half and the research project was discontinued (GSM Annual Report 2003).

Some of the operating issues with the Midas Spring system could be expected to occur for the Partial Pit Backfill With In-Pit Collection Alternative.

4.2.1.5.2.1.7 Waste Rock Dump Testing

GSM has conducted research and monitoring activities in waste rock dumps for a number of years. Some of this work included installation of monitoring wells and other tubes into waste rock material. The wells were more difficult to install than wells in solid rock formations.

For research conducted on the unsaturated West Waste Rock Dump Complex, several 2-inch steel pipes, up to 175 feet long, were drilled into the weathered waste rock for data collection (Schafer and Associates, 1996). After a few years, acid generated by sulfide oxidation coupled with some shifting in the waste rock resulted in blockage of the deepest pipe. Efforts to clear the pipe were unsuccessful. Shallower PVC pipes were also installed up to approximately 70

feet deep. Schafer and Associates (1996) noted that minor movements of waste rock deformed these access pipes, preventing sample acquisition at several sites during the first year of operation.

Some problems have been encountered with monitoring wells in the West Waste Rock Dump Complex. One well sanded in and another well was damaged during reclamation activities. Another well appears to have a separated casing, but this is unconfirmed. A damaged well in the area near the pit was replaced in 2004 because the well casing separated.

Operating issues encountered during monitoring in waste rock dumps could be expected to occur for the Partial Pit Backfill With In-Pit Collection Alternative.

4.2.1.5.2.2 Dewatering Experience at Other Mines

Mines have not typically been required to dewater backfill, so there are few examples. As documented in Section 4.2.1.3.1, no mines were found with similar amounts of backfill as described in the partial pit backfill alternatives (Gallagher, 2003c). At the San Luis Pit in Colorado, which had a maximum depth of about 140 feet of backfill, about one in five pumps fail due to shifting backfill, which deforms the installations. Precipitation and clogging of well screens in ARD plumes have affected wells at the Climax and Grasberg Mines.

Groundwater has been a concern in the Butte Mining District ever since the early mineshafts encountered water at depths of 20 to100 feet below ground level. To allow underground and open pit mining in the area, the groundwater level was lowered by pumping. Prior to cessation of open pit mining in the Berkeley Pit in 1982, dewatering was occurring at a rate of 4,000 to 5,000 gpm. The pumping system was located in the Kelley Mine Shaft west of the Berkeley Pit from the 1960s to 1982 (Canonie, 1994). Dewatering from underground sumps allowed underground mining in Butte for almost 100 years. Pumping from the underground workings for over 20 years effectively lowered the water table during open pit mining.

Montana Resources has pumped water from a floating barge in the Berkeley Pit to recover copper in the precipitation plant with minimal operational problems (S. Czehura, Montana Resources, personal communication, August 2004).

In summary, several factors could affect maintenance of the dewatering wells under the No Pit Pond Alternative. The agencies would require GSM to install and maintain a remote monitoring system for wells, pumps, pipelines, powerlines, etc. to minimize the need for workers to be in the pit and to ensure water is kept as low as possible in the crusher reject. GSM would have to replace any wells that failed.

4.2.1.6 Storm Water Runon/Runoff Management

Surface water runoff from storms and snow melt would be diverted around the open pit. As part of the final reclamation of the site, GSM would construct permanent storm water controls concurrently with site reclamation. As described in Section 2.4.2.5, storm water diversions designed to carry the flow from a 100-year, 1-hour storm event would be constructed around the pit perimeter to prevent as much surface water as possible from entering the pit. The storm water diversions would be designed and sized, installed to grade, lined with a geosynthetic liner to reduce infiltration into the pit rock under the diversions, covered with 3 feet of soil and/or riprap depending on location and the design flow of the diversion, and revegetated where appropriate.

The only storm water that would enter the pit would be direct precipitation on the pit disturbance area and runoff from areas where diversions would not be possible due to topographic constraints. It is estimated that 99 percent of the storm water around the pit area could be diverted away from the pit (Telesto, 2003a).

4.2.1.6.1 Maintenance Requirements

The maintenance requirements for the diversions would include regular monitoring of the system integrity and gradient to ensure proper function.

Some settling may occur where the diversions are constructed on unconsolidated materials, which would affect the ability of a diversion to route water away from the pit area over time. If the gradient changed from settling resulting in low spots, the diversion would have to be returned to the proper gradient, resoiled and seeded as necessary. Eventually, portions of the diversions would need to be reconstructed completely or at least have sediment accumulations and/or rockfalls from upgradient slopes removed. If 99 percent of storm water cannot be diverted, the amount of water needing treatment would increase.

4.2.1.7 Soil Cover

4.2.1.7.1 Soil Cover Maintenance Requirements

As described in Section 2.4.2.6, GSM has proposed a 3-foot soil cover on the pit floor area, pit benches, and roads, totaling 53 acres of revegetation. Seven acres have already been revegetated within the pit boundary area. Another 68 acres around the pit would be reclaimed with 3 feet of soil and revegetated. Any acreage revegetated in the pit would need to be monitored for rock raveling and sloughing, backfill settling, erosion, and noxious weeds. Highwall rock that has raveled or sloughed would have to be removed, the affected area covered with new soil, and reseeded. Areas that have settled would have to be filled to grade with additional soil. Eroded areas would need to be repaired, resoiled and

reseeded. Noxious weeds would have to be controlled. One hundred fifty-eight acres would not be resoiled in the pit.

As described in Section 4.2.1.3.2, some grading and/or dozing of the backfill surface may be needed if the crusher reject settled. This would affect the soil cover and more soil would have to be placed and reseeded.

As described in Section 4.2.1.2.2, the pit bottom would eventually be covered with rocks raveling off the highwalls and/or highwall rock from sloughing. The soil cover would be covered with the rocks. GSM would have to haul more backfill to reestablish the flat working surface and haul in new soil and reseed the soil.

4.2.1.8 Water Treatment

The 1997 Draft EIS, Chapter IV, Section IV.B.6.e and Appendix A evaluated the water treatment system for all water pumped from the pit. The treatment plant would be a standard lime treatment system located below Tailings Impoundment No. 2 (Figure 1-2). This system would be similar to the operational water treatment plants at GSM and Montana Resources in Butte. The 1998 ROD approved the water treatment plant with a design capacity, including contingencies, of 392 gpm, which included the 65 gpm of pit inflows (54 gpm plus 20 percent contingency) then projected for the No Pit Pond Alternative (Table 4-2). No changes to the treatment system have been proposed since the 1998 ROD. The treated pit water would be disposed of in a percolation pond below Tailings Impoundment No. 2. The revised pit water balance completed for this SEIS identified that 25 to 27 gpm would have to be pumped to the treatment plant under the No Pit Pond Alternative (Telesto, 2006).

The 1997 Draft EIS assumed that the pit would not discharge into surrounding aquifers. Total water collected and treated, with contingencies, included 25 gpm from the East Waste Rock Dump Complex, 200 gpm from Tailings Impoundment No. 1, and 25 gpm from Tailings Impoundment No. 2 in the 1997 Draft EIS, Appendix A, Table 2-1.

Table 4-2 compares 1997 Draft EIS inflows to the water treatment plant with SEIS predictions. In the No Pit Pond Alternative in this SEIS, total water, from all sources needing treatment, would be 250 gpm compared to 392 gpm in the 1997 Draft EIS. The water treatment plant is designed to handle this amount of water. GSM is bonded for 392 gpm as a contingency in case inflows are more than predicted.

Table 4 - 2. Water Treatment Plant Inflows (gpm) for the No Pit Pond Alternative

Facility	1997 Draft EIS[1]	SEIS
Tailings Impoundment No. 1	200	100
Tailings Impoundment No. 2	25	25
West Waste Rock Dump Complex	77	77
East Waste Rock Dump Complex	25	21
Pit	65	25 to 27
TOTAL	392	248 to 250

[1]1997 Draft EIS, Appendix A, Table 2-1; volumes include contingencies.

4.2.1.8.1 Additional Sludge Management Requirements

The new water balance completed for this SEIS concluded that from 25 to 27 gpm from the pit would need to be treated under the No Pit Pond Alternative. The quality of the water assumed to be treated in the 1997 Draft EIS was not as poor as that to be treated under this SEIS (See Section 4.3.3.1.1.2.1 and Table 4-5). More sludge would be produced per gallon of treated water. Because the volume of pit water requiring treatment in the SEIS is approximately one-third of the volume expected in the 1997 Draft EIS, the overall sludge management requirements would be similar to, or less than, those evaluated in the 1997 Draft EIS, Chapter IV, Section IV.B.1.e.

4.2.1.8.2 Additional Operating Requirements

The water treatment system in this SEIS is the same as that evaluated in the 1997 Draft EIS and, as shown in Table 4-2, there would be less water to treat from the pit.

There would be no additional operating requirements under the No Pit Pond Alternative from those analyzed in the 1997 Draft EIS.

4.2.1.9 Flexibility for Future Improvements

The flexibility for future improvements and potential for utilization of new technologies was not evaluated in the 1997 Draft EIS for pit reclamation alternatives. This is an important issue because of the risks and uncertainties associated with backfilling the GSM pit.

4.2.1.9.1 Potential for Utilization of New Technologies

As stated above in Section 4.2.1.5.1, 25 to 27 gpm of water would need to be treated under the No Pit Pond Alternative. The water would be pumped out of 100 feet of backfill. As described in various sections above, this can be done

although it would be more difficult in weathering, unconsolidated, settling, waste rock than native, unweathered rock.

The acidic water would require regular maintenance and replacement of pumps and other dewatering well components, as discussed in Section 4.2.1.5.2.

GSM has evaluated the potential to treat or at least pretreat pit water in-situ. During pumping from the pit sump in 2002-2003, GSM added carbon sources such as alcohol and sugars to the pit in an attempt to pretreat the pit water in the rubble at the bottom of the pit. The test was partially successful in improving pit water quality (GSM 2002 Annual Report). GSM initiated a new test during the mill shutdown (GSM, 2004). This new test was approved by the agencies (DEQ and BLM, 2004). Pretreating the pit water would increase the operational life of dewatering system components by reducing corrosion.

Research has been conducted on treating pit water with carbon sources, microbes, etc. in various locations around the world, for example, the Berkeley Pit in Butte and the Gilt Edge Mine in South Dakota. If an alternative to pumping and treating were developed in the future, it would be easier to pretreat pit water in an open body of water than in waste rock. It is easier to pump and mix carbon sources, microbes, etc. evenly in an open body of water than in saturated waste rock backfill.

If pit water had to be treated in saturated backfill, it would be easier to treat it in the less than 600,000 cubic yards of pit backfill and rock projected to fall to the bottom of the pit over time in the No Pit Pond Alternative than it would be in the much larger volumes of rock placed in the pit under the partial pit backfill alternatives.

4.2.1.9.2 Consequence of Failure of Dewatering System

If the dewatering system failed under the No Pit Pond Alternative, a pit pond would form. Pit water balance studies were completed for the Pit Pond Alternative, which was considered but dismissed in Section 2.5.4. These studies concluded that, for the Pit Pond Alternative without pumping pit water, the water level would rise and stabilize at the 4,635-foot elevation with no discharge. The results of the water balance studies performed for the Pit Pond Alternative can be applied to the No Pit Pond and Underground Sump alternatives.

Under the No Pit Pond Alternative, 25 to 27 gpm would be expected to flow into the pit (Telesto, 2006). Less than 10 percent of the water would leave the pit through fractures.

The principal consequence of failure of this alternative would be the potential creation of an ARD-impacted pit pond. Under the No Pit Pond Alternative, the agencies have assumed that the pit would eventually contain 600,000 cubic

yards (900,000 tons) of backfill and highwall rock that would ravel and slough over time. The additional 600,000 cubic yards of material would raise the pit floor from 4,625 to 4,742 feet. The water level in the backfill would remain below the surface of 4,742 feet because of the increased surface area of the pit floor and evaporation. Water remaining in the backfill would be below the 5,050-foot elevation at which water would begin to seep out of the pit at the colluvium-bedrock contact on the east side of the pit. Since a pond is unlikely to form, no adverse impacts to groundwater outside the pit would be anticipated. Water could be pumped out of the over 200 feet of pit backfill for treatment, if needed.

4.2.2 Partial Pit Backfill With In-Pit Collection Alternative (Proposed Action)

4.2.2.1 Design and Constructibility of the Alternative

4.2.2.1.1 Proven Design

As in the No Pit Pond Alternative, 100 feet of crusher reject would be placed in the bottom of the pit as backfill for use as a sump. Then, under the Partial Pit Backfill With In-Pit Collection Alternative, the rest of the backfill would be hauled to the pit rim and end dumped to an average 5,400-foot elevation. Finally, the upper highwall would be reduced by cast blasting and dozing until the 2H:1V final slope was achieved. Up to 11 dewatering wells from 775 to 875 feet deep would be drilled on the 5,400-foot elevation backfill surface. The wells could be built from the bottom up as stand pipes in leach pads are constructed. However, the backfill would have to be hauled down into the pit and placed in layers, putting workers at greater risk, or it would have to be end dumped from pit margins, putting the standpipes at risk from damage during dumping. These wells would experience the same risks as they would if drilled from the surface, including shearing and crushing from compaction, silting, and corrosion. Replacement wells would need to be drilled from the surface. It is estimated that 27 to 42 gpm would be pumped out of the wells (Telesto, 2006). Seventeen gpm would be routed off the backfill as storm water runoff or would be used up through evapotranspiration (Telesto, 2003a).

As described in the No Pit Pond Alternative, Section 4.2.1.3 and the pit backfill analog study (Gallagher, 2003c), pits have been backfilled in Montana and elsewhere. There are no known instances of pits receiving 875 feet of backfill in Montana or elsewere. Cast blasting is a common mining technique but has had limited use in reclamation. Cast blasting of the upper highwall as a reclamation technique to reduce portions of the highwall has been discussed at GSM, Zortman, and Landusky (William Maehl, personal communication, 2004), and proposed at the McDonald Gold project (Seven Up Pete Joint Venture, 1994).

It is technologically feasible to haul backfill, cast blast highwalls, and install wells in a pit at closure. Backfilling by hauling to the bottom of the pit and end dumping, and by hauling and end dumping from the pit rim, is a proven design. Cast blasting to reduce highwalls has not been used as much in regrading pit slopes but cast blasting is a proven design in and of itself. Dewatering a backfilled pit by installing wells is a proven design in shallow pits; it is not a proven design in pits with up to 875 feet of backfill, especially those with acidic water (HCI, 2002). It is possible to install wells in unsaturated, unconsolidated waste rock, as shown by the two-inch steel casings installed in the West Waste Rock Dump Complex at GSM for data collection (Schafer, 1995a). Monitoring

wells have been constructed in the shallow portions of some of the waste rock dumps, but all these wells have failed over time.

Backfilling and cast blasting are proven designs. It is technically feasible to backfill and cast blast, but the agencies have not documented any other pits the size of the GSM pit that have been backfilled by end dumping and cast blasted to reduce highwalls. Dewatering backfill from this depth has also not been documented (HCI, 2002; Kuzel, 2003; Gallagher, 2003c).

4.2.2.1.2 Ability to Construct the Alternative at GSM

The pit backfill analog study conducted for this SEIS did not find any hardrock mine in which such a large pit was backfilled and allowed to become saturated with groundwater (Gallagher, 2003c). No long-term water quality monitoring records exist at the backfilled mines or flooded underground mines studied sufficient to indicate whether the reclamation goals at those mines were achieved.

As described in the No Pit Pond Alternative, crusher reject would be hauled to fill the bottom 100 feet of the pit. After the 100 feet of crusher reject has been placed under the Partial Pit Backfill With In-Pit Collection Alternative, GSM would start hauling and end dumping waste rock from the pit rim. End dumping would continue to an average elevation of 5,400 feet. Total backfill volume would be 33,300,000 cubic yards (50,000,000 tons). As noted in the pit backfill analog study, attempts were made to identify and describe a backfilled mine pit with a similar depth to GSM's pit. None could be found.

The upper 1,000 feet of the highwall would be reduced by cast blasting and dozing 11,900,000 cubic yards (17,900,000 tons) of highwall rock to create 2H:1V slopes. If cast blasting failed on any portion of the highwall, waste rock could be hauled and end dumped after construction of new access roads. Cast blasting would enhance the overall stability of the pit highwall by reducing the highwall slope, but would disturb an additional 56 acres (Figure 2-4).

Installing dewatering wells at this depth in unconsolidated waste rock backfill and pumping the estimated 27 to 42 gpm of pit groundwater from this depth is more difficult than the same activities in 100 feet of crusher reject and pumping the 25 to 27 gpm under the No Pit Pond Alternative. Four dewatering wells could be installed successfully, although it would be difficult in 775 to 875 feet of backfill (J. Finley, Telesto, personal communication, 2003).

No actual case histories or examples of dewatering wells pumping as little as 27 to 42 gpm in up to 875 feet of weathered waste rock backfill have been found (HCI, 2002; Gallagher, 2003c). Wells of this depth and capacity could be pumped successfully, at least initially, but wells and pumps would need repeated maintenance and replacement, as described in Section 4.2.1.5.2.

There would be more problems developing and implementing the Partial Pit Backfill With In-Pit Collection Alternative than the No Pit Pond Alternative at closure because of the larger volume and depth of backfill needed, the amount of cast blasted material, and the problems drilling dewatering wells up to 875 feet deep in unconsolidated waste rock in order to maintain the pit as a hydrologic sink.

The agencies expect that the dewatering wells would fail repeatedly over time due to settling and corrosion. In addition, it is doubtful that 27 to 42 gpm could be continually pumped from these wells from this depth without allowing time for the water table to rebound in the backfill sump (HCI, 2002). Therefore, water may not be restricted to the lowest level of the pit. Fluctuation in the water table would degrade the quality of the water and increase settling (Telesto, 2003e). The quality of the water in the acidic backfill would result in problems with corrosion. Scaling and biofouling are not expected to be a problem because of the low pH of the pit water. The agencies would require GSM to replace dewatering wells that failed.

Waste rock samples show fairly high permeability for the projected pit backfill, based on 18 field samples from the surface and 5 laboratory samples from depths up to 15 feet (Telesto, 2003d). Sample results were similar to those reported by Herasymuik (1996). They were considered to be representative of the entire East Waste Rock Dump Complex. Herasymuik's maps and cross sections show that his sample pits were dug during re-excavation of the East Waste Rock Dump Complex after the 1994 ground movement. Samples were taken from waste rock dumps less than 6 years old in the unsaturated zone less than 100 feet deep. The applicability of these results to conditions under a much greater thickness of fill, over an indefinite period of time, and under varying degrees of saturation, is uncertain. The analysis shows that permeability would decrease over time due to compaction in up to 875 feet of backfill and accelerated weathering due to rehandling waste rock during backfilling operations (see Section 4.2.2.3.1).

Additional permeability testing of potential backfill material under simulated load conditions (such as that in a backfilled pit) was conducted subsequent to the Draft SEIS (Telesto, 2005). The results indicate that under 450 feet of backfill, the hydraulic conductivity can decrease to 10^{-6} cm/s, and that under 900 feet of backfill, the hydraulic conductivity can decrease to 10^{-7} cm/s (Telesto, 2005). This additional evaluation indicates that control of pit seepage with vertical wells would likely not be reliable.

4.2.2.2 Pit Highwall

The stability analysis for the Partial Backfill Alternative is summarized in Appendix H of the 1997 Draft EIS. The analysis concluded that there would be

no important difference in overall pit highwall stability between an open pit and a partially backfilled pit. The pit highwall under the Partial Pit Backfill With In-Pit Collection Alternative would be slightly more stable in comparison with the No Pit Pond Alternative in this SEIS because of the change in the pit highwall slopes due to cast blasting to achieve overall 2H:1V slopes in the highwall.

4.2.2.2.1 Pit Highwall Stability

Under the Partial Pit Backfill With In-Pit Collection Alternative, the pit from the 4,525-foot to the 5,400-foot elevation would be backfilled with 33,300,000 cubic yards (50,000,000 tons) of waste rock material from the East Waste Rock Dump Complex. Cast blasting and dozing of the upper pit highwall would be used to create the 2H:1V slope on the highwall above 5,400 feet (Figure 2-4 cross section of pit). Cast blasting would enlarge the pit by 56 acres from 218 to 274 acres in order to achieve overall 2H:1V slopes and provide haul routes for pit backfilling and soil replacement (Figure 2-4).

No pit highwall would remain exposed under this alternative. Backfilling the pit under this alternative would eliminate pit highwall raveling and sloughing over time. Cast blasting would also enhance the inherent stability of the pit highwall by reducing the slope to 2H:1V from a current average of 0.8H:1V. Thus, the long-term stability of the pit highwall would be greater than the No Pit Pond Alternative. The agencies assumed in the No Pit Pond Alternative that the highwall would ravel and have occasional failures of up to 100,000 cubic yards over time. The agencies expect that disturbance caused by cast blasting under the Partial Pit Backfill With In-Pit Collection Alternative would be greater than the total acreage disturbed by eventual highwall failures assumed under the No Pit Pond Alternative over time (Section 4.2.1.2.2).

The SEIS's stability conclusions are supported by subsequent technical reviews and additional analyses (Brawner, 2005; Golder, 2005). These studies concluded that, with the pit slopes covered, highwall raveling and other failure modes are not important stability issues under the partial pit backfill alternatives.

4.2.2.2.2 Pit Highwall Maintenance Requirements

The highwall would be covered by backfill, cast blasted highwall rock, and soil. Some physical and chemical weathering would occur over time in the highwall rock, especially in localized seep areas. No highwall maintenance would be needed under the Partial Pit Backfill With In-Pit Collection Alternative.

4.2.2.3 Backfill

4.2.2.3.1 Backfill Maintenance Requirements

As described in Section 4.2.1.5.2, geotechnical testing of the backfill and cast blasted materials showed that settlement would be expected during and after backfilling operations (Telesto, 2003e). The backfilled pit area would be subject to more settlement than a large portion of the waste rock dump complexes because of the thickness of the backfill. Settlement of waste rock used as backfill would be reduced because the waste rock has already weathered in the waste rock dump complex. Some backfilled areas in deep portions of the pit could still settle as much as 150 feet (Telesto, 2003d). Since the backfill material would be composed of mainly gravel and sand sized particles from the waste rock deposits (Herasymuik, 1996) and would be applied in an unsaturated condition, the agencies expect that 60 to 75 percent of settlement will occur during the backfilling process.

Although long-term settlement in the 775 to 875 feet of backfill would not affect pit highwall stability, it is likely that depressions would occur in the backfill material and the cast blasted material on the 2H:1V slopes due to the settlement of the backfill. These depressions would become locations for surface water accumulation and infiltration and could be sites where saturation and instability of the soil cover would be initiated. Monitoring would be needed to watch for settling of the cover. If ponding occurred, more soil would need to be replaced to restore the gradient. Settlement along a storm water diversion could result in erosion on the face of the revegetated slopes. To minimize this impact, monitoring of bench gradients and reestablishment of gradients would be needed over time. For maintenance of soiled and revegetated areas, see Section 4.2.1.7. For maintenance of storm water diversions, see Section 4.2.2.6.1.

If the Partial Pit Backfill With In-Pit Collection Alternative were selected, the agencies would consider requiring GSM to delay final reclamation of the backfill and cast blasted material until monitoring of the backfill indicated that most of the settlement had occurred. Even though 60 to 75 percent of the settling would have occurred, dewatering well failure would continue due to the remaining 25 to 40 percent settling as waste rock in the backfill weathered over time. Dewatering well failure and subsequent saturation of the backfill would lead to up to 50 feet of additional settlement (Telesto, 2003d). In addition, problems of corrosion discussed in Section 4.2.2.5 would still be a problem.

4.2.2.4 Underground Workings

4.2.2.4.1 Impacts to Pit Facilities Due to Subsidence Related to Underground Mining

Impacts due to subsidence in the underground workings would be the same as under the No Pit Pond Alternative. The underground workings and portal monitoring and maintenance plan could not be implemented because access to the underground would be covered with over 500 feet of backfill material.

Localized failures of overhead rock in the underground workings over time could result in subsidence, especially in seep and fault areas where chemical weathering would be increased. This subsidence could cause the backfill to further settle, potentially affecting the dewatering wells in the backfill. The agencies would require GSM to backfill the underground workings remaining after Stage 5B to minimize settlement. The agencies would require GSM to replace wells that failed.

4.2.2.5 Groundwater/Effluent Management System

4.2.2.5.1 Operation Requirements (Number of Wells)

The 1997 Draft EIS, Chapter II, Section II.B.7.b described a pit dewatering system for the Partial Backfill Alternative consisting of a series of wells drilled to depths below the 5,050-foot elevation. In this SEIS, the dewatering system for the Partial Pit Backfill With In-Pit Collection Alternative would consist of up to 11 wells from 775 to 875 feet deep to keep the groundwater level as close as possible to the 4,525-foot pit bottom elevation (Telesto, 2006).

The wells would be drilled until they penetrate the bedrock under the backfill. As described in Section 2.4.3.3, boreholes would be 10 to 12 inches in diameter and would be lined with 6-inch-diameter stainless steel casing. The bottom 200 to 300 feet of the casing would be slotted. The water level would be maintained as low as possible in the backfill. A stainless steel submersible pump equipped with electronic sensors to maintain optimum drawdown would be installed in each well. The water would be routed by pipeline to the water treatment plant prior to being discharged back into the ground, away from the pit area, in percolation ponds, LAD areas, or other approved locations.

The dewatering wells would be subject to settlement and corrosion. Scaling and biofouling are not expected to be a problem because of the low pH of the pit water. The agencies would require GSM to replace wells that failed. The permeability of the backfill would decrease as described in Section 4.2.2.1.2.

4.2.2.5.2 Maintenance of Capture Points

Installation and long-term operation of dewatering wells in backfill under this alternative would be similar to the No Pit Pond Alternative but more problematic. The main differences are:

- Drilling and completing wells through an additional 675 to 775 feet of unconsolidated backfill;
- Effectiveness of pumping from wells in an additional 675 to 775 feet of heterogeneous backfill, some of which would be fine-grained and of lower permeability (Figure 4-1);
- Maintaining the water table as low as possible at similar pumping rates and higher lifts (HCI, 2002);
- Maintaining pump intake openings, slotted casings, and sensors that would be subject to corrosion and silting and sanding;
- Maintaining structural integrity of dewatering wells due to long-term settlement of the additional 675 to 775 feet of backfill; and
- Decreases in permeability, especially in the lower portions of the pit, would reduce the ability to capture groundwater.

Drilling to depths greater than 100 feet within acidic waste rock backfill presents unique problems and challenges. Problematic issues when drilling in poorly consolidated or unconsolidated materials such as backfill include: poor circulation, low recovery, reduced drilling rates, and decreased borehole stability. Telesto Solutions, Inc. completed a drilling program in southern Arizona in a blasted, unconsolidated, brecciated formation similar to conditions that would occur in pit backfill at GSM (J. Finley, Telesto, personal communication, 2003).

During the drilling program, circulation was lost approximately 60 feet below ground surface and all attempts to regain circulation were unsuccessful. In the course of drilling a 400-foot boring, over 1,000 bags of bentonite were added to the drilling fluid in an unsuccessful attempt to regain circulation. Enough chip-seal (cedar fibers and cotton hulls) was used to completely clog the recirculation system on the drilling rig with no effect on recovery of drilling solution or underground geologic material.

Drilling rates averaged approximately 1.5 feet per hour because of the difficulty in drilling through the rubble material and the time required to mix the large quantities of drilling mud. The potential for the bore hole to collapse required drilling with very frequent casing advancement (casing was advanced approximately every 5 to 10 feet) further slowing the drilling rates. Borehole stability was enough of a concern that drilling the rubble material required around-the-clock drilling operations so that borehole collapse would be minimized. Drilling in the breccia formation required approximately three times the amount of hours anticipated by both experienced geologists and drillers, and

approximately 15 times longer than drilling in natural, unconsolidated formations. Drilling through unconsolidated breccia material is not impossible, but difficult and expensive. Installing wells at depths greater than 400 feet would be more difficult.

A screening level feasibility assessment of pumping from a backfilled pit was performed for this SEIS (Telesto, 2003e). The Partial Pit Backfill With In-Pit Collection Alternative was evaluated for its functionality, conformance to industry standards, and construction feasibility. Permeability of the backfill is the principal property determining the effectiveness of dewatering wells. If permeability is too low, groundwater would not move into a well fast enough or from a sufficient region to allow the pump to function properly (HCI, 2002).

All available permeability values for waste rock samples from GSM, consisting of 23 tests (5 laboratory and 18 field tests), were summarized (Telesto, 2003d). The geometric mean of these data was approximately $1x10^{-3}$ cm/sec. The 90th percentile value was approximately $1x10^{-4}$ cm/sec. All samples were from the upper 15 feet of the waste rock dump. Telesto concluded that after backfilling, the permeability could be expected to range from $1x10^{-3}$ to $1x10^{-5}$ cm/sec. Based on this analysis, it was concluded in the Draft SEIS that initially the permeability of the backfill would be adequate for dewatering under this alternative. Additional permeability testing of potential backfill material under simulated load conditions (such as that in a backfilled pit) was conducted subsequent to the Draft SEIS (Telesto, 2005). The results indicate that under 450 feet of backfill, the hydraulic conductivity can decrease to 10^{-6} cm/s, and that under 900 feet of backfill, the hydraulic conductivity can decrease to 10^{-7} cm/s (Telesto, 2005). This additional evaluation indicates that control of pit seepage with vertical wells would likely not be reliable. The analysis shows that the permeability would decrease over time under 875 feet of backfill with variable or incomplete drainage. In addition, cementing of the acidic backfill by oxidation byproducts in the water could eventually create some perched water tables or areas of limited permeability around the wells.

The analysis shows that the 100 feet of crusher reject would be permeable at first but would weather and break down over time. This would limit the ability to pump out water effectively, because of accumulation of fines in the backfill. In addition, the acidic water and waste rock is full of microbes, which accelerate the ARD reaction and could increase potential biofouling, depending on the pH of the water. Acidic water increases corrosion. Scaling, from iron hydroxide formation, and biofouling would not reduce permeability over time because of the low pH of the pit water.

Due to the low flows of 27 to 42 gpm and problems with pumping small amounts of water, the water level could not be steadily maintained at the 4,525-foot elevation. The water level would rebound up in the slotted casing and then be pumped intermittently to effectively pump from that depth. This would increase

the production and flushing of oxidation products as the water level fluctuates in the backfill and not meet the goal of maintaining the water level as low as possible in the crusher reject, which minimizes the flushing of oxidation products.

Based on backfill settlement discussed in Section 4.2.3.3, up to 150 feet of settlement could occur over the deepest part of the pit over several years (Telesto, 2003e). If the water table rebounded because dewatering wells could not effectively pump from 775 to 875 feet deep, this could cause up to an additional 50 feet of settlement in the saturated portion of the backfill over about 100 years.

Corrosion, scaling, and potential biofouling were addressed in the No Pit Pond Alternative Section 4.2.1.5.2. The corrosive nature of the backfill groundwater, along with the settlement of the backfill, could create difficulties in the implementation of the Partial Pit Backfill With In-Pit Collection Alternative. The following measures may lessen the impacts due to settling and corrosion, but not eliminate them:

- Allow time for settlement, which could result in less than 10 percent of the ARD leaving the pit along faults and other flow paths if the water level rose to the 5,050-foot elevation;
- Wait until backfill saturation approaches the design elevation of the dewatering well screens, which would increase the flushing of oxidation byproducts and allow more settlement to occur in the saturated backfill;
- Install additional dewatering wells in case of failure due to settlement and corrosion; and,
- Install shallower wells as an alternate water level control, which would increase the amount of water escaping the pit, flushing of oxidation byproducts, and settlement.

The agencies considered the risks and uncertainties of all these measures. Settlement is the highest risk to well integrity. Some measures would increase the potential for creating more acidic water, which would move out of the pit and have to be captured down gradient. These measures do nothing to reduce corrosion, which is a risk to well failure. These measures do nothing to improve the ability to drill 875-foot wells in unconsolidated waste rock backfill.

If pumping cannot maintain the water level at the 4,525-foot elevation, groundwater within the pit backfill would become more acidic and metal laden than typical pit water. Due to the 775 to 875 feet of backfill and the need for deep wells, control of the groundwater level would be more difficult under the Partial Pit Backfill With In-Pit Collection Alternative than the No Pit Pond Alternative.

As described in Section 4.2.2.3, 150 feet of settling of the 775 to 875 feet of backfill would occur over time. This settling could affect the integrity of the well casings causing casings to separate in the compacting and consolidating material. Settling could also affect pumps, electrical components, monitoring equipment and pipelines requiring periodic repair and replacement. Additional settling would occur if the backfill becomes inundated. Most settlement would occur within the first few years of placement, but 25 to 40 percent would occur over a longer period, after wells would likely be installed, subjecting them to stresses sufficient to buckle or shear the casings requiring complete replacement of wells over time. This could lead to elevated groundwater levels in the backfill, increasing ARD migration out of the pit if the water table rose above the 5,050-foot elevation (Telesto, 2003a).

Up to 11 wells would be required, compared to two to three wells under the No Pit Pond Alternative, to provide adequate capacity to create an effective cone of depression in the 775 to 875 feet of backfill because of reduced permeability. The corrosive nature of the pit backfill groundwater and potential damage to the well casings from settling backfill indicate that redundancy would also be necessary to maintain effective dewatering. Because of the risks and uncertainties, GSM would be required to replace wells that failed.

As described in Section 4.2.1.5.2, corrosion of the screens and pumps, well casings, electrical components, monitoring equipment and pipelines from the acidic crusher reject and acidic water in the backfill would cause periodic need for repair and replacement of dewatering system components. To prevent wells from silting in, wells must be installed with a gravel pack and the pump periodically raised in the well casing.

Other problems with maintenance include trying to maintain pumps at low pumping rates and high lifts and replacing wells and pumps over time. These are more problematic than the No Pit Pond Alternative, which would require less lift and similar pumping rates in the 100 feet of backfill. The only capture points would be the up to 11 dewatering wells. The underground sump could not be used as a contingency in this alternative because the underground workings would be buried under more than 500 feet of backfill.

4.2.2.6 Storm Water Runon/Runoff Management

4.2.2.6.1 Maintenance Requirements

Maintenance requirements for storm water diversions under this alternative would be the same as under the No Pit Pond Alternative.

The storm water runon/runoff system to keep surface water out of the pit under the Partial Pit Backfill With In-Pit Collection Alternative would be similar to the No Pit Pond Alternative except the location would be different due to the 56 acres of new disturbance created by cast blasting. More than 99 percent of the storm water would be diverted away from the pit (Telesto, 2003a).

Benches would be created on the 2H:1V slopes every 200 vertical feet. Storm water diversions would be constructed on the benches and graded to route water out of the pit area. The backfilled surface of the pit would be graded at 4.3 percent to drain surface water out the eastern rim of the pit at the 5,350-foot elevation.

On the 2H:1V slopes, dozer basins would be created as on the waste rock dump complexes to control erosion until vegetation becomes established. Rocky soils containing up to 45 percent coarse fragments would help to limit erosion and sedimentation in storm water diversions.

The analysis shows that 0.5 to 1.1 inches of annual precipitation would infiltrate into the pit backfill as on waste rock dump slopes (HSI, 2003). This is included in the 27 to 42 gpm of pit seepage that would be collected and treated (Telesto, 2006).

The risks and uncertainties for storm water diversions outside of the pit would be the same as under the No Pit Pond Alternative. Settlement in the backfill as described in Section 4.2.2.5.2 could cause depressions, which would become locations for surface water accumulation and infiltration and could be sites where saturation and instability of the soil cover would be initiated. Settlement along a storm water diversion could result in erosion on the face of the reclaimed slopes. To minimize this impact, monitoring of bench gradients and reestablishment of gradients would be needed over time.

4.2.2.7 Soil Cover

4.2.2.7.1 Soil Cover Maintenance Requirements

As described in Section 2.4.3.6, GSM has proposed a 3-foot soil cover on 274 acres to be revegetated in the pit area. Monitoring of backfill settlement would be the same as described in the No Pit Pond Alternative, Section 4.2.1.7, but there would be more settlement because of the depth of the backfill. There would be

no raveling and sloughing affecting the cover. Any acreage revegetated in the pit would need to be monitored for erosion and noxious weeds. Eroded areas would need to be repaired, resoiled and reseeded. Noxious weeds would have to be controlled.

As described in Section 4.2.3.3, some grading and/or dozing of the backfill surface would be needed as the backfill settles. This would affect the soil cover and more soil would have to be placed and reseeded.

GSM has previously constructed soil covers on waste rock dump complexes and tailings impoundments. On waste rock dump complexes, the dump material and covers have not become saturated, and settlement or erosion problems have been limited. GSM monitors storm water diversions on waste rock dumps annually. If settling occurs, the gradient would be re-established as necessary. On Tailings Impoundment No. 1, where the tailings were saturated and are dewatering over time, settlement has resulted in the necessity for maintenance activities (GSM, 2002c). GSM monitors settlement and soil is replaced as needed to prevent ponding on the impoundment surface and to provide drainage off the impoundment surface.

After cast blasting and dozing the pit highwall to a 2H:1V slope, a 3-foot soil cover with 45 percent rock fragments would be placed over the waste rock and revegetated. GSM's consultant concluded that, in the partial backfill alternatives, a drainage layer would be necessary to keep the soil from slumping in saturated areas on steep 2H:1V slopes (Telesto, 2003d). GSM has been successful in reclaiming long steep slopes at the mine site. The agencies have concluded that the subsurface drainage layer to keep soil from slumping in saturated backfill is not needed in either of the partial pit backfill alternatives. The agencies concluded that small localized stability problems would exist for the soil cover if the soil became saturated, especially if the backfill was relatively impermeable in localized areas. Small localized failures could develop because highwall seeps could flow laterally through and saturate the cover. Seep water would be acidic and would contaminate soils and impair revegetation success if allowed to contact the soil cover. To improve soil cover stability in these localized areas after a failure, the seep would be located and dewatered, contaminated soil would be replaced with clean soil, and the area would be revegetated. In highly permeable areas, such as the Corridor Fault, seep areas would be more common.

Steam vent monitoring under the current permit would be modified to include the pit area as well as the waste rock dumps.

4.2.2.8 Water Treatment

The water treatment plan under the Partial Pit Backfill With In-Pit Collection Alternative would be the same as the No Pit Pond Alternative. In the 1997 Draft

EIS, Chapter IV, Section IV.B.7.b, the agencies predicted that up to 50 gpm of pit water would be treated under the Partial Backfill Alternative. Because an estimated 27 to 42 gpm of pit water would be treated under the Partial Pit Backfill With In-Pit Collection Alternative as a result of the new water balance completed for this SEIS (Telesto, 2006), no change in treatment or disposal methods would be needed.

No other pit discharge was assumed in the 1997 Draft EIS for the Partial Backfill Alternative. The water treatment plant approved in the 1998 ROD had a total design capacity of 392 gpm. No changes in treatment plant design capacity would be needed for the Partial Pit Backfill With In-Pit Collection Alternative.

4.2.2.8.1 Additional Sludge Management Requirements

The quality of the water assumed to be treated in the 1997 Draft EIS was not as poor as the water quality projections of pit water to be treated used in this SEIS (see Table 4-5 in Section 4.3.3.1). In addition, the weathering processes observed in the waste rock dump complexes would continue to produce oxidation byproducts in the unsaturated portion of the backfill. Jarosite in the saturated portion of the backfill would prevent reducing conditions from developing, as can sometimes occur within submerged materials because of the lack of oxygen (see Section 4.3.3.1.1.2.1). Jarosite would allow further production of acid. Jarosite is soluble under the foreseeable conditions and would be expected to dissolve slowly adding dissolved ferric iron to the water. Pumping of pit water to maintain the water level at the 4,525-foot elevation would limit saturation of the backfill and impacts from jarosite dissolution.

More sludge would be produced per gallon of treated water compared to the No Pit Pond Alternative, but the volume of pit water to be treated would be about one-third. So the sludge management requirements would be similar to or less than that analyzed in the 1997 Draft EIS.

4.2.2.8.2 Additional Operating Requirements

The water treatment system in this SEIS is the same as that evaluated in the 1997 Draft EIS. There would be less water to treat from the pit, so there would be no additional operating requirements at the water treatment plant.

Up to 11 dewatering wells would be located at the 5,400-foot elevation. If the water could be pumped out of the wells regularly without failure of the pumps due to corrosion, routing water from the 5,400-foot elevation would be easier than from the 4,625-foot elevation under the No Pit Pond Alternative.

If the drought has affected the seepage predictions on this SEIS and more water would need to be treated than expected, the existing permit stipulation based on

Measure W-6, adding capacity to the water treatment plant, approved in the 1998 ROD as Stipulation 010-9 would be adequate.

4.2.2.9 Flexibility for Future Improvements

4.2.2.9.1 Potential for Utilization of New Technologies

It is estimated that 27 to 42 gpm of water from the pit would need to be treated under the Partial Pit Backfill With In-Pit Collection Alternative.

The water would need to be pumped out of 775 to 875 feet of acidic backfill. This may be possible, although it would be more difficult in the weathering, unconsolidated, acidic waste rock. The acidic water would require regular maintenance and replacement of pumps and other dewatering system components. Because of the problems with maintaining wells in waste rock and the difficulty in removing water from the deeper backfill, the partial pit backfill alternatives offer less potential for utilization of new technologies.

The Partial Pit Backfill With In-Pit Collection Alternative would be less able to accommodate future technological improvements in controlling water quality and quantity than the No Pit Pond Alternative. It would be easier to redesign the system in 100 feet of backfill than in 775 to 875 feet of backfill. If necessary, it would be easier to remove 111,000 cubic yards (167,000 tons) than 33,300,000 cubic yards (50,000,000 tons) of backfill and 11,900,000 cubic yards (17,900,000 tons) of cast blasted highwall rock.

As discussed in the No Pit Pond Alternative (Section 4.2.1.9.1), research is being conducted on treating pit water with chemicals, carbon sources, microbes, etc. in various locations around the world. If an alternative to pumping and treating were developed in the future, it would be easier to treat pit water in an open body of water than in backfill.

If pit water had to be treated in backfill, it would be easier to treat it in the 111,000 cubic yards (167,000 tons) of waste rock in the pit under the No Pit Pond Alternative than it would be in the 33,300,000 cubic yards (50,000,000 tons) of waste rock placed in the pit under the partial pit backfill alternatives.

Pit water balance studies completed for this SEIS concluded that for the Pit Pond Alternative, dismissed in Section 2.5.4, the water level would rise and stabilize at the 4,635-foot elevation due to evaporation of water from the highwall and pit pond. The agencies expect that the 27 to 42 gpm of pit inflow would not leave the pit under the Partial Pit Backfill With In-Pit Collection Alternative. If the dewatering system failed with the volume of backfill placed in the pit, the water would eventually begin discharging at the 5,050-foot elevation. It would be easier to implement treatment systems using chemicals, carbon sources, microbes, etc. in an open body of water than in a pit backfilled with waste rock.

4.2.2.9.2 Consequence of Failure

If implementation of this alternative failed for any reason, the water level would rise in the backfill above the 5,050-foot elevation. An estimated 27 to 42 gpm would eventually leave the pit and would have to be captured down gradient as under the Partial Pit Backfill With Downgradient Collection Alternative. Other treatment technologies that could be implemented in the backfilled pit would be limited. If downgradient collection were not installed, eventually groundwater quality standards would be exceeded at the mixing zone boundary. The time that it would take for groundwater standards to be exceeded at the mixing zone boundary would depend on the mode of failure. If failure occurs because groundwater by-passes the deeper portions of the pit where groundwater is to be collected, the time for groundwater standards to be exceeded would be relatively short. If failure occurs because the collection wells in the pit malfunction, then the time available to address failure of this alternative would be greater.

4.2.3 Partial Pit Backfill With Downgradient Collection Alternative

4.2.3.1 Design and Constructibility of the Alternative

4.2.3.1.1 Proven Design

Backfilling and cast blasting under the Partial Pit Backfill With Downgradient Collection Alternative would be the same as for the Partial Pit Backfill With In-Pit Collection Alternative.

The dewatering system design would be more complex, requiring at least 26 dewatering wells, 10 monitoring wells, and 2 acres of new road and pipeline and power line disturbance, but is a proven design. Pumping out of drainages from wells up to 200 feet deep in various geologic formations is done regularly. The water quality down gradient would not cause as much failure of dewatering system components due to corrosion from acidic water as pumping from backfill in the pit under the No Pit Pond and Partial Pit Backfill With In-Pit Collection alternatives. Scaling from iron hydroxide formation and potential biofouling could increase because of the higher pH of the captured water. Limited scaling has occurred at GSM (Section 4.2.1.5.2.1.5).

4.2.3.1.2 Ability to Construct the Alternative at GSM

The volume and depth of backfill and cast blasted material would be the same for both partial pit backfill alternatives.

No wells would be constructed in the backfill under this alternative. At least 26 dewatering wells and 10 monitoring wells would be constructed down gradient of the pit in Rattlesnake Gulch (Figure 2-7).

Installing dewatering wells at GSM in similar geologic materials has been done successfully. Based on GSM's experience in drilling monitoring and pumpback wells, the agencies expect that only a maximum of 80 percent of groundwater in a given capture system would likely be captured in these wells because of uncertainty about flow paths, heterogeneities in the aquifer, and operations and maintenance outages. More wells would probably be needed to attempt capturing a sufficient percentage of the pit discharge. The Tailings Impoundment No. 1 south pumpback system (Figure 3-5) would have to be maintained as well. Two capture systems, operating at a combined capture efficiency of approximately 96 percent, would be required to prevent water quality violations at the mixing zone boundary. The 96 percent capture efficiency may not be achievable based on GSM's experience capturing Tailings Impoundment No. 1 seepage. Based on their experience, the agencies believe a maximum capture efficiency of 80 percent per system is potentially achievable.

GSM has been capturing Tailings Impoundment No. 1 seepage since the 1983 leak of tailings solution through the improperly constructed bentonite slurry cutoff wall. Chronologies of events about the leak and capture systems from 1983 through 2003 have been compiled (GSM 1991 Annual Report: Table 1; Spectrum Engineering, 2004: Appendix A).

Four pumpback wells were constructed in 1983. In 1986,15 pumpback wells were in place. In 1991, 22 more pumpback wells were constructed. As detailed in various Annual Reports, new monitoring wells and pumpback wells have been constructed and old wells have had to be decommissioned or replaced regularly. Wells were refurbished in 1995 and 2001. In 2004, 16 pumpback wells were still being pumped, and a total of 52 monitoring wells and three surface water stations were being sampled to track the leakage from Tailings Impoundment No. 1 (Portage Environmental, 2004).

Various reports have been prepared since 1980 about the impoundment, documenting the problem and addressing agencies' comments about GSM's ability to contain the seepage (SHB, 1980, 1982, 1983, 1985, 1986, 1987, and 1989b; DSL, 1987 and 1988; Hydrometrics, 1991, 1994, 1997; Keats, 2001; HSI, 2003; Spectrum Engineering, 2004; Portage Environmental, 2004). Despite continual upgrading of the wells, some seepage is escaping the south pumpback system. Data suggest slow migration of seepage away from Tailings Impoundment No. 1 (GSM 1998, 1999, and 2000 Annual Reports). There also is a vertical component to the seepage migration as well (GSM 2000 Annual Report).

Keats (2001) concluded the second and third rows of pumpback wells were not completely capturing the seepage. Keats recommended treatment at the source area rather than adding pumpback wells. This was due in part to the difficulty in defining smaller scale contaminant pathways. GSM has tested in-situ injection in the area with DEQ and EPA approval to achieve treatment at the source since the Keats report was completed.

Portage Environmental, Inc. reviewed the GSM monitoring well program in 2004. It summarized the level of contamination in all wells in the report. The majority of wells below the pumpback system still show some cyanide, nitrate, or metal contamination. It is hard to define how much of that is from the 1983 leak or from the continued migration of seepage past the capture systems. The agencies and GSM continue to review sampling results and modify the seepage containment system to prevent violations at the permit boundary.

A new well was constructed in 2004 to identify sources of nitrate that may or may not be related to the mine (Spectrum Engineering, 2004). Another new well drilling program was approved in October 2004 to identify the nitrate source(s) in

the area wells. Each new well placed in the Bozeman Group shows variable geology and the discontinuity of lithologic units within the Group.

The Bozeman Group is a variable aquifer and has been the subject of many studies since 1980. GSM is capturing the majority of the seepage from Tailings Impoundment No. 1, a process that uses a large number of pumpback and monitoring wells (Hydrometrics, 1996) that continue to be necessary. Some seepage continues to escape the pumpback system. Efforts continue to ensure that violations do not occur at the mixing zone boundary.

For this SEIS, modeling indicated that two capture systems achieving an overall capture efficiency of approximately 96 percent would be needed to prevent violations at the mixing zone boundary (HSI, 2006). GSM's experience since 1983 trying to capture Tailings Impoundment No. 1 seepage indicates this may not be achievable. Based on their experience, the agencies believe a maximum capture efficiency of 80 percent per system is potentially achievable

DEQ has been addressing concerns with capture system efficiency at other sites, including the Zortman, Landusky, CR Kendall, and Black Pine mines, and PPL Montana power plants in Colstrip. At Colstrip, PPL Montana continues to have problems containing seepage through a variable Tertiary aquifer. None of these systems capture all seepage.

Containing groundwater in the pit offers a greater degree of control of contaminants than trying to capture contaminants in a variable aquifer closer to the mixing zone boundary. Treatment at the source (*i.e.*, pumping directly from the pit sump) in the No Pit Pond or Underground Sump alternatives is easier to achieve than treating by collection and pumping from downgradient wells. Adding more water to the Rattlesnake Gulch flowpath may accelerate and complicate existing capture system collection efforts.

4.2.3.2 Pit Highwall

4.2.3.2.1 Pit Highwall Stability

Pit highwall stability under this alternative would be similar to the Partial Pit Backfill With In-Pit Collection Alternative.

Stability of the pit highwall would not be affected by the water table rebounding and stabilizing at the 5,260-foot elevation (Telesto, 2003d).

4.2.3.2.2 Pit Highwall Maintenance Requirements

Pit highwall maintenance requirements would be similar to the Partial Pit Backfill With In-Pit Collection Alternative.

Highwall maintenance would be similar to the Partial Pit Backfill With In-Pit Collection Alternative.

4.2.3.3 Backfill

4.2.3.3.1 Backfill Maintenance Requirements

The type of backfill maintenance requirements would be similar for the No Pit Pond and partial pit backfill alternatives. Under this alternative, the backfill would become saturated to the 5,260-foot elevation as the water table rebounded.

As described in Section 4.2.2.5.2, up to 150 feet of settlement would occur over time. Sixty to 75 percent would occur during backfilling. The rest would occur over the long term (Telesto, 2003d). The settlement tests performed on the waste rock specimens were analyzed in a dry condition to mimic end dumping that would occur during backfilling. Following the settlement tests, the specimens were inundated with water to simulate water filling of the pit. This inundation by water added an additional 50 feet average settlement (Telesto, 2003d).

Settlement could extend below the toe of the steep 2H:1V slopes, causing the slope to slough. If the function of the storm water diversions on the benches is affected, gullies would form. One way to mitigate this adverse impact would be to delay installing the drainage controls and soil cover until the backfill has sufficiently stabilized, as described in Section 4.2.2.5.2. According to the consolidation tests conducted using the backfill material, settlement would stop once the backfilled pit has been fully inundated. After inundation of the pit, the settlement could be as much as 167 to 200 feet. During this delay, downgradient dewatering would have to continue. It would take nearly 61 years for saturation of the pit backfill to reach equilibrium at the 5,260-foot elevation.

The maintenance requirements would be more than for the Partial Pit Backfill With In-Pit Collection Alternative due to the additional 50 feet of settling from inundation of the backfill to the 5,260-foot elevation. As for the Partial Pit Backfill With In-Pit Collection Alternative, additional soil would be needed to bring the backfill up to grade and to restore the function of the storm water diversions.

4.2.3.4 Underground Workings

4.2.3.4.1 Impacts to Pit Facilities Due to Subsidence Related to Underground Mining

Impacts due to subsidence in the underground workings under this alternative would be the same as under the Partial Pit Backfill With In-Pit Collection Alternative.

The risks and uncertainties would be similar to the Partial Pit Backfill With In-Pit Collection Alternative.

4.2.3.5 Groundwater/Effluent Management System

The water balance for this SEIS concluded that for the Partial Pit Backfill With Downgradient Collection Alternative, an estimated 27 to 42 gpm would discharge from the backfilled pit (Telesto, 2006). The primary objective of the Partial Pit Backfill With Downgradient Collection Alternative would be to try to avoid pit dewatering completely by letting the pit water table rebound in the backfill and letting the pit effluent discharge into the regional groundwater system. The pit discharge would move down primary and secondary groundwater flow paths, partially attenuate, and mix with ambient groundwater. Approximately 77 to 143 gpm of ambient groundwater, East Waste Rock Dump Complex seepage, and pit discharge would be collected in Rattlesnake Gulch using the existing Rattlesnake Gulch dewatering wells and the Tailings Impoundment No. 1 capture system supplemented with additional wells as described in Section 2.4.4.3 (HSI, 2006).

4.2.3.5.1 Operation Requirements (Number of Wells)

As described in Section 2.4.4.3, at least an additional 26 downgradient capture wells, and 10 monitoring wells would be needed to capture and monitor pit seepage and ambient groundwater. Groundwater quality standards would be met at the mixing zone boundary if 96 percent or greater overall capture efficiency is achieved from two capture systems (HSI, 2006). More wells may be needed as described in Section 4.2.3.1.2. An overall 96 percent capture efficiency may not be achievable based on GSM's experience with Tailings Impoundment No. 1 seepage, as described in Section 4.2.3.1.2. As described in Section 4.3.4.1.2.2.1, as a result of trying to capture an overall 96 percent of the combined pit seepage, East Waste Rock Dump Complex seepage, and ambient groundwater to meet groundwater standards at the mixing zone boundary, an approximate 77 to 143 gpm of groundwater would be collected in the process. The number of wells and the need to collect additional water reflect the uncertainties of effective contaminant collection in the Tdf/colluvial aquifer (the primary pit flowpath), and collection of contaminants in the fractured bedrock aquifer (the secondary pit flowpaths).

4.2.3.5.2 Maintenance of Capture Points

Maintenance of downgradient collection wells would be less problematic than those in acidic backfill. As described above, capturing groundwater at distances down gradient of the pit introduces uncertainty as to the effectiveness of capture of all contaminated groundwater in the heterogeneous Bozeman Group and in fracture flow systems. It also necessitates the collection of a greater volume of groundwater.

The collection wells would need to be monitored and maintained regularly to ensure pumping efficiency. Additional operator time would be needed to access the wells around the pit. The powerlines, pipelines and access roads would also need to be maintained. The well casings in natural geologic formations would not be subject to the settling effects of the backfill. In addition, the pumped water quality could be better for a few years due to short-term buffering by the aquifer and mixing with ambient groundwater, which would limit corrosion and extend pump life. Once the attenuation and buffering capacity of the aquifer is used up (projected to be a few tens of years (HSI, 2003)), then water quality would be similar to the pit water quality. GSM has been maintaining capture wells below the impoundments for many years (Section 4.2.1.5.2.1.5) and the costs of this maintenance are well documented. Bond would be calculated to cover the additional costs of maintaining the complex collection system. Approximately 77 to 143 gpm of ambient groundwater, East Waste Rock Dump Complex seepage, and pit discharge would have to be collected to meet groundwater standards at the mixing zone boundary (HSI, 2006). This may not be achievable, as described in Section 4.2.3.1.2. Based on their experience, the agencies believe a maximum capture efficiency of 80 percent per system is potentially achievable

4.2.3.6 Storm Water Runon/Runoff Management

4.2.3.6.1 Maintenance Requirements

The storm water runon/runoff management maintenance requirements for this alternative would be the same as the Partial Pit Backfill With In-Pit Collection Alternative.

The storm water runon/runoff management maintenance risks and uncertainties for this alternative would be the same as the Partial Pit Backfill With In-Pit Collection Alternative.

4.2.3.7 Soil Cover

4.2.3.7.1 Soil Cover Maintenance Requirements

The soil cover maintenance requirements for this alternative would be greater than the Partial Pit Backfill With In-Pit Collection Alternative due to more settlement in the saturated backfill.

Risks and uncertainties with soil cover maintenance would be the same as the Partial Pit Backfill With In-Pit Collection Alternative.

4.2.3.8 Water Treatment

The water treatment plan under the Partial Pit Backfill With Downgradient Collection Alternative would be the same as all other alternatives. In the

modeling completed for this SEIS, it was estimated that of the from 27 to 42 gpm that would discharge from the pit, 96 percent would need to be collected in the existing pumpback collection systems and at least an additional 26 downgradient wells. The agencies have estimated that approximately 77 to 143 gpm would be collected and treated as a result of trying to capture the combined volume of pit seepage, East Waste Rock Dump seepage, and ambient groundwater needed to prevent water quality impacts at the mixing zone boundary. In the 1998 ROD, the agencies predicted treatment of 102 gpm of pit water under the No Pit Pond Alternative. The present treatment plant design capacity would be adequate (Table 4-2). The additional water would not require a change in treatment or disposal methods. The quality of the water from the saturated pit would be worse because of the geochemical processes associated with weathered acidic, metal laden waste rock backfill of the pit under both saturated and unsaturated conditions.

4.2.3.8.1 Additional Sludge Management Requirements

As mentioned above, with downgradient collection, approximately 77 to 143 gpm would be collected and treated under this alternative to prevent impacts at the mixing zone boundary.

The quality of the water in the backfill would be the same as in the Partial Pit Backfill With In-Pit Collection Alternative. Jarosite in the saturated portion of the backfill would prevent reducing conditions from developing, as can sometimes occur within submerged materials because of the lack of oxygen. Jarosite would allow further production of acid. Metals release would occur during the dissolution of jarosite because ferrous iron usually predominates below the water table. The flow from the unsaturated portion of the backfill above the water table would continue to contribute low pH water with high metals concentrations to the pit discharge for hundreds of years. The rock along the primary and secondary flow paths from the pit has limited natural attenuation capacity, or ability to reduce the metals concentration or increase pH of the groundwater flow (HSI, 2003; Telesto, 2003e). The sludge management requirements would be roughly the same between alternatives with and without pumping because the chemical mass produced is roughly the same (Robertson GeoConsultants, 2003).

4.2.3.8.2 Additional Operating Requirements

Under the Partial Pit Backfill With Downgradient Collection Alternative, 26 more collection wells and 10 more monitoring wells would be needed in the dewatering system than with the Partial Pit Backfill With In-Pit Collection Alternative. This would require more spur pipelines and powerlines to the main pipeline and powerline to transport the captured water to the treatment plant. The agencies have assumed an additional 2 acres would be disturbed for new roads, pipelines, and powerlines to the wells.

The extra wells, pipelines, powerlines and roads would require more monitoring time than the dewatering systems for other alternatives. The collection and monitoring wells under this alternative would not be subject to other problems that the wells in the acidic backfill would be subject to such as settling damage to casings and corrosion. The collection and monitoring wells could be subject to limited problems with corrosion, scaling, and potential biofouling of pumps and screens, etc., due to increased pH of the captured water. The wells would also not be as deep and therefore would not have the problems with high lift out of the deep backfill. The water treatment plant could require additional operating funds due to the increased water quantity (approximately 77 to 143 gpm) that would be collected in the downgradient capture wells, as compared to the other alternatives. The 300 to 366 gpm volume from all sources needing treatment under this alternative would still be less than the 392 gpm water treatment plant capacity approved in the 1998 ROD.

4.2.3.9 Flexibility for Future Improvements

4.2.3.9.1 Potential for Utilization of New Technologies

The potential for utilization of new technologies under this alternative would be similar to the Partial Pit Backfill With In-Pit Collection Alternative except that future backfill water treatment methods that require injection of chemicals, carbon sources, microbes, etc. would be more difficult because of the lack of wells in the backfill. Wells could be installed. If treatment were attempted outside of the pit, a dispersed plume may be more challenging to track and contain.

4.2.3.9.2 Consequence of Failure

If implementation of this alternative failed for any reason, modeling indicates that groundwater quality standards would be exceeded at the mixing zone boundary. This alternative would put contaminated water into groundwater flowpaths that connect to the Jefferson River alluvial aquifer and Jefferson Slough.

4.2.4 Underground Sump Alternative

4.2.4.1 Design and Constructibility of the Alternative

4.2.4.1.1 Proven Design

The pit would not be backfilled under this alternative. Waste rock would remain stored and capped above the water table in the East Waste Rock Dump Complex. Dewatering would occur in an underground sump. This has already been done at GSM during operations. The Colorado Division of Minerals and Geology (CDMG), the Nevada Department of Natural Resources and Conservation (NDNRC), and the Nevada Department of Environmental Protection (NDEP) were contacted regarding dewatering (Kathy Gallagher, GSM consultant, personal communication, 2003). The NDNRC and NDEP could not provide specific methods of dewatering for individual mine sites, merely stating that the majority of mines in Nevada were dewatered. Mines listed by NDEP included Pipeline (Placer Dome America), Gold Quarry (Newmont), Meikle (Barrick Gold Strike), and Robinson (Quadra). Underground operations listed as being dewatered from a sump included Leeville (Newmont), Hollister (Hecla), and Getchell (Placer Dome America). The CDMG data are presented below in Table 4-3.

Table 4 - 3. Examples of mines being dewatered and their dewatering methods

Mine	Limited Backfill	Underground Sumps	Pit Ponds
Berkeley Pit - Butte, Montana		From the 1960s to 1982, Anaconda Company dewatered Berkeley Pit from Kelley Shaft at 4,000-5,000 gpm (Canonie, 1994).	Montana Resources has pumped from the pit lake for process water.
Mayflower Mine - Montana		In 1997 dewatered from sump at 1,582 feet, pump @ 1,200 level .	
Battle Mountain – San Luis Colorado	Controlled dewatering/rinse of pit backfill for indefinite time. Treated and released.		
Homestake - Bulldog, Colorado		Dewatered below lowest adit level to develop sub-adit level. Treated and released.	
Cotter Corp - Schwartzwalder, Colorado		Dewatered below adit level (formerly) to develop sub-adit workings. Treated and released.	
Climax Molyb. Co - Climax, Colorado		Perpetual pumping from main shaft to prevent overflow of groundwater out shaft. Treated and released.	
Gilt Edge, South Dakota			Treated in the pond, pumped from the pond, and discharged.

During stripping of waste rock for Stage 5B, GSM dewatered the mine from 7/27/2006 through 1/16/2007 via an underground sump. Water is drained to the sump through two drill holes from the 4,650-foot elevation. At closure, GSM would have to drill holes from the 4,525-foot elevation to an underground sump to drain water that would collect in the pit bottom.

It is technically feasible to install pumps in the underground workings at closure. During a portion of the underground operation, GSM dewatered the pit and underground working from a sump in the underground, as described in Section 4.2.1.5.2.1.4. Maintaining hydrologic connection between the pit bottom and the underground for dewatering has been successful. Periodic maintenance would be needed to ensure access to the 4,550-foot-elevation portal, to maintain the underground workings, and access to the sump. Pumps would need to be replaced as in other alternatives. Pipelines and powerlines may be damaged periodically by rock falls in the underground workings or from the highwall, but

these are readily observable and can be corrected immediately. In addition, preventive measures, such as covering pipelines with rock after installations, can be routinely implemented to minimize potential impacts.

4.2.4.1.2 Ability to Construct the Alternative at GSM

No crusher reject would be placed in the pit under this alternative. The only work needed to construct this alternative would be to redesign the underground dewatering system and develop the 4,550-foot elevation portal for future access.

The agencies would require GSM to submit a plan for development, maintenance and monitoring of a portal at a suitable elevation to maintain secondary access for dewatering. This would provide long-term access to the dewatering system for repair and maintenance and to provide safety for underground workers.

4.2.4.2 Pit Highwall

4.2.4.2.1 Pit Highwall Stability

Pit highwall stability under this alternative would be essentially similar to the No Pit Pond Alternative.

Under the Underground Sump Alternative, no crusher reject or other material would be backfilled in the bottom portion of the pit. Dewatering of the pit would occur from within the existing underground workings. As the groundwater level in the pit highwall is drawn down during mining and maintained following mining, the pit highwall would remain stable. The portal at the 4,550-foot elevation could be destroyed by the failures described by the agencies under the No Pit Pond Alternative. The agencies would require GSM to submit a plan for development, maintenance, and monitoring of a portal at a suitable elevation to allow secondary access, dewatering in the future, and to protect workers in the pit and underground.

4.2.4.2.2 Pit Highwall Maintenance Requirements

Pit highwall maintenance requirements under this alternative would be similar to the No Pit Pond Alternative.

Depending on the location and nature of highwall raveling and sloughing over time, there is a possibility that access to the 4,550-foot portal and the underground dewatering system could be lost. If this were to occur, portions of the pipelines and powerlines could be lost. The water table would begin to rebound in the underground workings. GSM would have to reestablish the 5,700-foot safety bench and access to the 4,550-foot portal, if possible, and repair any damaged dewatering components. The agencies would require GSM to submit a plan for development, maintenance and monitoring of a portal at a

suitable elevation to maintain secondary access for dewatering. There would be no impacts outside of the pit.

4.2.4.3 Backfill

4.2.4.3.1 Backfill Maintenance Requirements

Not applicable to the Underground Sump Alternative.

4.2.4.4 Underground Workings

4.2.4.4.1 Impacts to Pit Facilities Due to Subsidence Related to Underground Mining

Impacts due to subsidence under this alternative would be similar to the No Pit Pond Alternative except localized failures of overhead rock in seep and fault areas could occur over time affecting access to the dewatering system in the underground workings. A monitoring and maintenance plan would be needed to ensure continued access to repair the dewatering system and to ensure worker safety. The monitoring and maintenance plan would be applied to both the 4,550-foot and contingency portal locations.

4.2.4.5 Groundwater/Effluent Management System

The principal objective of the Underground Sump Alternative would be to maintain the pit as a hydrologic sink, keeping the groundwater level below the final pit bottom at the 4,525-foot elevation.

4.2.4.5.1 Operation Requirements (Number of Wells)

There would be no new wells constructed under this alternative. Some drill holes would be needed to direct pit water to the underground sump. Construction of the underground dewatering system would be completed during the last phase of Stage 5B mining operations. The dewatering system would be designed and constructed to maintain the groundwater level 25 to 75 feet below the final pit bottom elevation of 4,525 feet by pumping from the Deep Baja stope (Figure 2-8). Risks and uncertainties for wells would be less than the No Pit Pond Alternative, since no new wells are required and no wells would be installed in any backfill.

The modeling for this SEIS estimates that from 25 to 27 gpm of water would have to be removed from the underground workings. In addition, the modeling indicates that pumping may not be required from the two existing vertical highwall wells (PW-48 and PW-49), since evaporation and the heat produced by the reaction from sulfide oxidation would likely remove over 75 percent of the volume of this water as it migrated down the highwall. However, at least initially, the

highwall wells would continue to be operated (GSM, 2002a). Operation requirements for the underground dewatering system would be less than the operation requirements for wells under the partial pit backfill alternatives. All water would be collected at one point.

4.2.4.5.2 Maintenance of Capture Points

The only capture point would be the sump in the underground workings. Access to the underground would be needed. The agencies expect that highwall failures over time would bury the 4,550-foot elevation portal. The agencies would require GSM to submit a plan for development, maintenance and monitoring of a portal at a suitable elevation for long-term access. The agencies would bond for maintenance of access and regular repair and replacement of dewatering system components.

4.2.4.6 Storm Water Runon/Runoff Management

4.2.4.6.1 Maintenance Requirements

Storm water management maintenance requirements would be comparable to the No Pit Pond Alternative.

Surface water would be diverted around the open pit. Surface water that drains into the pit would be removed to the underground sump through bore holes drilled to connect the pit with the underground workings. As part of the final reclamation of the site, GSM would construct permanent storm water controls concurrently with site reclamation. These controls would minimize or eliminate surface water inflow from entering the open pit. More than 99 percent of the surface water would be diverted away from the pit (Telesto, 2003a).

Risks and uncertainties would be similar to the No Pit Pond Alternative.

4.2.4.7 Soil Cover

4.2.4.7.1 Soil Cover Maintenance Requirements

This alternative is similar to the No Pit Pond Alternative except there would be 1.3 fewer acres to maintain in the pit. Any rocks off the highwall that escape the safety benches may end up on the soil covered revegetated areas on pit roads and benches. These areas may either need to be cleared or resoiled and reseeded. There would be no backfill material, and therefore no cover on backfill material.

4.2.4.8 Water Treatment

This alternative would be similar to the No Pit Pond Alternative and an estimated 25 to 27 gpm would be pumped from the underground workings (Telesto, 2006). Water quality in the underground sump would be more predictable than water in the backfill.

4.2.4.8.1 Additional Sludge Management Requirements

The 25 to 27 gpm produced in the underground workings would be comparable to the water quality in the No Pit Pond Alternative. The amount of water needing treatment would be less than the 102 gpm used to design the water treatment plant capacity for the No Pit Pond Alternative in the 1997 Draft EIS.

The water quality used in the 1997 Draft EIS was better than the water quality used in this SEIS, so additional sludge would be created. The agencies have concluded that the amount of additional sludge would be minimal and would not produce changes in the sludge management plans at the water treatment plant. Because no waste rock would be removed from the East Waste Rock Dump Complex to be used as backfill, jarosite, adsorbed metals, and other oxidation byproducts would remain relatively immobile in the waste rock dump complex.

4.2.4.8.2 Additional Operating Requirements

Pumping from the underground sump at the 4,450-foot elevation out of the 4,550-foot elevation portal and then to the water treatment plant would result in the need for some additional pipelines and powerlines over those needed for the No Pit Pond Alternative.

The agencies expect that the 4,550-foot elevation portal would be buried by rocks raveling and sloughing off the highwalls over time. GSM would be required to maintain access at a contingency portal location. This would require additional powerlines, pipelines, and maintenance of access roads in the decline to ensure integrity of the dewatering system and provide a secondary escapeway for workers over time. The agencies have assumed the safety risk to workers in the pit is less than in the No Pit Pond Alternative. The risk to workers from using the underground sump for the dewatering system would be less than the risk to workers maintaining the pit dewatering system in the No Pit Pond Alternative below the 1,775-foot highwall on a 1.3-acre working surface.

4.2.4.9 Flexibility for Future Improvements

4.2.4.9.1 Potential for Utilization of New Technologies

The Underground Sump Alternative would have the potential for utilization of new technologies being developed for use in the underground workings to collect or

treat seepage. Access would have to be maintained to the underground workings to implement these new technologies or wells could be drilled into the underground workings. Research is being conducted on treating pit water with carbon sources, microbes, etc. in various locations around the world, including the Berkeley Pit in Butte. It would be easier to implement treatment systems using chemicals, carbon sources, microbes, etc. in an open body of water in the underground sump than in a pit backfilled with waste rock.

The acidic water would cause regular maintenance and replacement of pumps and other dewatering well components, as in other alternatives. Although no waste rock is placed in the pit under this alternative, the water is still expected to be acidic because of its exposure to pit rock containing sulfides and the 200,000 cubic yards (300,000 tons) of rock that ravels and sloughs to the bottom over time.

GSM has researched the potential to treat or at least pre-treat pit water in-situ. During 2002-2003, GSM added carbon sources such as alcohol and sugars to the pit in an attempt to pre-treat the pit water in the rubble at the bottom of the pit. In addition, GSM proposed treating water that is collecting in the underground workings. This new test has been approved by the agencies (DEQ and BLM, 2004). Pretreating the pit water would increase the operational life of dewatering system components by reducing corrosion. Depending on the success of the test, it may cause potential biofouling and scaling. This test was never conducted.

This alternative offers the opportunity to test and potentially treat water either in an open pond, in the event of failure, or in an open water body in the underground workings. The agencies believe the potential for using new technologies is maximized in the Underground Sump Alternative.

4.2.4.9.2 Consequence of Failure

The consequence of failure of a dewatering system in the underground workings in this alternative would be that the underground workings below the pit would flood and the pit would begin to fill with water. The consequence of failure would be similar to the Pit Pond Alternative, which was dismissed in Section 2.5.4. If the Underground Sump Alternative failed, then the No Pit Pond Alternative or a Pit Pond Alternative could be implemented. Under the Pit Pond Alternative, the water table would rise to the 4,635-foot elevation and stabilize. Pit water would be readily observable, and corrective action would be taken before the pit substantially flooded. The revised pit water balance model predicts an inflow range from 25 to 27 gpm (Telesto, 2006). It would take approximately 230 to 262 days for 8.3 million gallons of water in the underground workings to reach the pit bottom elevation of 4,525 feet.

Under the No Pit Pond Alternative, 111,000 cubic yards (167,000 tons) of crusher reject would be backfilled. The agencies have assumed that up to 100,000 cubic yards (150,000 tons) of rock would ravel and slump off the pit highwall over time, and another 100,000 cubic yards (150,000 tons) would slough. Even with this total volume of rock in the bottom of the pit, the water table would not rise above the 5,050-foot elevation where water would begin to discharge from the pit.

The Underground Sump Alternative would be similar to the No Pit Pond Alternative in terms of ravel and slough as well as water table stabilization level. Even with the rock that would ravel and slough to the pit bottom, the water level would stabilize below the 5,050-foot elevation (Telesto, 2003a). If the dewatering system was to fail and a pit pond formed, water could be treated in the pit, pumped to the treatment plant from the pit pond and treated, or the No Pit Pond Alternative could be implemented as a contingency. This alternative offers the most flexibility for future changes in water treatment methods.

4.3 ENVIRONMENTAL ISSUES

4.3.1 Environmental Impacts of Current Mining Operations

4.3.1.1 Waste Rock Impacts to Water Quality and Quantity

Springs around the pit area are shown in Figure 3-5. No impacts to spring water quality during mining operations were identified in the 1997 Draft EIS, Chapter IV, Section IV.B. Since 1998, the only documented change in water quality in pit area springs was to Stepan Spring. Stepan Spring, below the South Dump, showed water quality impairment, which was attributed to waste rock dump runoff (Gallagher, 2003c). This site was reclaimed, with pH and dissolved metals levels improving from 1999 to 2002, although total dissolved solids and sulfate generally remained above levels of 1989 to 1998. From 2003 to 2006, flow from Stepan Spring has diminished to intermittent, and pH has decreased somewhat (see Section 3.3.4). Stepan Original Spring emanates from a collapsed adit and represents regional groundwater that has traveled through mineralized zones (HSI, 2003).

The East Waste Rock Dump Complex buried an intermittent spring, Midas Spring, which may be associated with the buried Midas Adit and possibly associated with the Sunlight slip block discussed by Golder (1995a). Discharge from this spring may be in contact with waste rock, and the earliest measurements in 1990 indicate that it was acidic with elevated sulfate and metals. Midas Spring discharge is captured and conveyed to the water treatment plant.

Rattlesnake Spring and Bunkhouse Springs emerge in Rattlesnake Gulch, a natural drainage filled with debris flow and landslide deposits derived in part from mineralized portions of Bull Mountain. As described in Section 3.3.4, these springs receive flow from mineralized zones, which contain subsurface ferricrete deposits, and are believed to be representative of naturally mineralized groundwater. This analysis identified no definitive water quality trends indicating mining- or waste rock-related impacts (Gallagher, 2003a).

North Borrow Springs, located approximately 120 yards north of Tailings Impoundment No. 1, consists of a broad seepage area with flow rates ranging from 8 to 32 gpm. These springs were created when the North Borrow Area was excavated below the shallow water table. Spring water is now being intercepted by an underdrain system constructed beneath the Buttress Dump. The system conveys water by pipeline to Tailings Impoundment No. 2. The North Borrow Area excavation has been filled with material from the East Waste Rock Dump Complex to form the Buttress Dump. Flows from the underdrain system have been minimal since the Rattlesnake Gulch pumpback system was installed (Shannon Dunlap, GSM, personal communication to HSI, November 1, 2005).

Arkose Valley Spring and Sunlight Spring were both covered by the West Waste Rock Dump Complex after 1986 and do not have any surface expression. In order to lower the local potentiometric surface and prevent contact between water and waste rock, interception and infiltration facilities were constructed at both Arkose Valley Spring and Sunlight Spring in mid-1994. All work was completed prior to expansion of the West Waste Rock Dump Complex over the springs. No discharge or seepage of water has occurred from the West Waste Rock Dump Complex.

Storm water runoff from the waste rock dump complexes has been limited during mine life. Storm water that ran off was captured at the toe of the waste rock dump by berms and percolation ponds. No impacts were noted in downstream monitoring wells (GSM 2006 Annual Report).

4.3.1.2 Pit Impacts to Water Quality and Quantity

4.3.1.2.1 Pit Impacts to Groundwater

As groundwater enters the pit, it flows through zones of broken and disturbed rock, which contains 0.5 to 2.0 percent pyrite (Table 4-1). Atmospheric oxygen and dissolved oxygen in water percolating through the broken rock reacts with the pyrite, which leads to sulfide oxidation and generation of ARD. In addition, during precipitation events, water quality is degraded by the flushing of oxidation by-products, such as acid salts that have accumulated on the pit highwall from evaporation (Gallagher, 2003b) and from heat produced by sulfide oxidation.

As discussed in Section 3.3.3, water collected within the pit has been impacted by ARD during the life of the mine. Most of the seeps and springs emanating from the pit highwall have a pH ranging from 2 to 4 (Gallagher, 2003b). Freshly blasted highwall rock is primarily unoxidized and acid producing (Gallagher, 2003a; Schafer and Associates, 1994, 1996). GSM has conducted research on the pit sump water during operations. Water pumped from the pit sump from 2002 to 2003 had a median pH of approximately 4.5 and an average sulfate concentration of 16,400 mg/l.

Groundwater immediately upgradient of the pit is less affected by sulfide oxidation and is of better quality than pit water. Two vertical highwall dewatering wells (PW-48 and PW-49 as shown on Figure 3-5) located on the 5,800-foot elevation bench on the north highwall have been pumped to intercept groundwater upgradient of the pit. Monitoring results from these wells indicate that, although the water is of better quality than the pit water, it would require treatment to meet water quality standards (GSM, 2002a). The water quality from PW-48 is somewhat lower than PW-49, with median pH of 3.8 and median sulfate of 1,825 mg/l, compared to 5.9 and 1,605 mg/l, respectively for PW-49.

The 1997 Draft EIS, Chapter IV, Section IV.B.1.b indicated that ARD from the pit was not expected to impact local groundwater quality during mining operations. The 1997 Draft EIS concluded that mining would reduce the groundwater level around the pit area during operations. Pumping of water from the pit causes a cone of depression in the potentiometric surface of the bedrock aquifer surrounding the pit such that the net flow is into the pit creating a hydrologic sink (URS, 2001; Hydrometrics, 1995) (Figure 3-5 from GSM, 2002a).

Groundwater flows into the pit from all directions, controlled by geologic structures such as faults, fractures, dikes, and disturbed rock zones. The sources of pit inflows include direct precipitation over the pit, the local and intermediate groundwater systems, underground mine water, and groundwater released from storage (Telesto, 2003a). The groundwater capture zone of the pit extends from as little as 100 to 300 feet east and south of the pit rim to as much as 1,600 feet north of the pit rim (Telesto, 2003a). Hydraulic effects of the pit may extend greater distances from the pit along fracture zones.

As described in Section 3.3.7.2, faults and fractures control the permeability of the bedrock unit in the pit area and act as the conduits of groundwater flow into the pit. From 1995 through 2001, 43 pit highwall seeps were cataloged by GSM, some of which may be duplicative due to the changing pit configuration and seep locations over time (Gallagher, 2003b). The most seepage was found as the pit intersected the Corridor Fault. In general, while new seeps have been identified as the pit was deepened, total flow from seeps has not changed proportionately. Precipitation events were found to be responsible for the largest variations in pit highwall seep flows (Gallagher, 2003b). Gallagher (2003a) also described the geologic structural controls, lithologic controls, and engineering/blasting controls on pit highwall seepage. A disturbed rock zone caused by conventional blasting and mining extends several feet to tens of feet into the pit highwall. This zone tends to funnel pit highwall inflows downward, where the water may reach the pit bottom or emerge as pit highwall seeps.

The pit has been maintained as a hydrologic sink by pumping from the pit since at least 1991, when the first seeps developed during Stage 2 and 3 mining. Dewatering requirements were minimal until late 1991/early 1992 when the pit intercepted the Corridor Fault in the Stage 3 Pit. In July 2002, GSM installed a dewatering well in rubble in the bottom of the pit. The well was constructed to a depth of approximately 118 feet (bottom of hole elevation 4,748 feet). The well was pumped routinely from the end of July 2002 until July 2003 to keep the water level below the pit floor. In July 2003, the well was removed to allow mining of the rubble in the bottom of the pit. Based on pumping records, water inflow to the sump at the bottom of the pit averaged 27 to 30 gpm while the well was in service (see Section 4.2.1.5.2.1.3).

Two highwall dewatering wells (PW-48 and PW-49) have been pumped to intercept groundwater from the Corridor Fault area before it enters the pit. The

combined flow from these wells averaged approximately 18.2 gpm (PW-49 averaged 16 gpm, PW-48 averaged 2 gpm) (Telesto, 2006). In addition to the existing dewatering wells, horizontal drains have been installed and incorporated into the dewatering system as required to maintain safe operations. Less than 5 gpm of groundwater discharged into the underground mine and was collected in the underground sump and pumped out of the underground workings. Pumping did not occur after underground mining ceased in January 2004 through June 2006 (Shannon Dunlap, personal communication, 2006), because no water accumulated in the pit bottom. The underground sump at the 4,450 to 4,500-foot elevation has a 500,000 gallon capacity. Total storage in the underground workings is estimated to be 20,000,000 gallons.

Since the 1997 Draft EIS was published through 2003, water levels in wells near the pit have shown a strong downward trend as a result of regional drought conditions and pit dewatering (HSI, 2003; SEIS Figure 3-6). Water levels in R-18 declined from late 1997 until the monitoring well was mined out in September 1999.

The average annual total pit pumping rates for 2000, 2001, and 2002 were 36.4, 28.2, and 47.8 gpm, respectively (Gallagher, 2003a). The average annual total pit pumping rate for 2003 was 36 gpm (GSM, 2004b). Prior to 2000, monthly average pit pumping rates varied from 12 to 76 gpm (Hydrometrics, 2000). The 1997 Draft EIS, Chapter IV, Section IV.B.1.b reported that the minimum groundwater elevation in the pit in 1993 was approximately 5,400 feet. In 2002, the minimum pit groundwater elevation was approximately 4,700 feet. GSM is permitted to mine the pit to the 4,650-foot elevation, and the pit reached that depth in October 2003.

The hydrograph study found that there was a general decline in bedrock water levels from 1998 through 2003, but that it was difficult to make definitive conclusions regarding the causes (HSI, 2003). A decline in precipitation from 1998 into 2003 was found to have affected groundwater levels in bedrock wells at GSM. However, the general water level declines track with the trend of R-18 reasonably well, indicating that pit dewatering may be responsible for some portion of water level declines in the fractured bedrock aquifer, particularly in PW-14, located about 3,000 feet northwest of the pit (Figure 3-5).

During mine operations and during the 16 to 18-month mill shut down while Stage 5B waste rock was removed, water collecting in the pit bottom is transferred to the underground workings through drill holes that intercept both the underground workings and pit. Water collected in the underground workings can be either sprayed over blasted rock to control dust or pumped to a lined holding pond and then to the water treatment facility. Pumping from the underground had not occurred from 2004 through June 2006 (Shannon Dunlap, GSM, personal communication, 2006). GSM pumped 47,157,900 gallons from

7/27/2006 through 1/16/2007 (Kathy Gallagher, GSM, personal communication, 2007).

The water from the highwall dewatering wells may be mixed with treatment plant discharge and directed to the LAD infiltration basin, a lined pond for treatment, or Tailings Impoundment No. 2.

In summary, mining has caused a decline in the groundwater level around the pit area. This condition would continue through Stage 5B. The regional drought has contributed to the decline in groundwater level (HSI, 2003 and 2006). The regional drought may have also contributed to reduced levels of pit inflow as well as reduced estimates of water needing treatment.

4.3.1.2.2 Pit Impacts to Surface Water

The 1997 Draft EIS, Chapter IV, Section IV.B.1.b reported that discharges at springs and seeps in the vicinity of the pit have the potential to be impacted if the expanding cone of depression from pit dewatering intercepts interconnected hydrogeologic units and groundwater, which otherwise would discharge to the surface as springs. Because of the small (0 gpm to 32 gpm) variable spring flow rates and the complex nature of the hydrostratigraphic units, incremental changes in spring discharge have not been quantified (Table 3-1). The 1997 Draft EIS, Chapter III, Section III.B described the setting and general conditions for each of the known springs around the pit area, including Bunkhouse, Rattlesnake, Stepan, Stepan Original, and St. Paul springs (Figure 3-5). The long-term potential impact to Stepan Spring, identified as most likely to be impacted by pit dewatering, was a reduction in flow. This reduction could bring the flow from the typical range of 0.8 to 2.8 gpm to a range from 0.1 to 1 gpm. Other springs could be expected to have a smaller reduction in flow. If the groundwater cone of depression has not reached equilibrium at the conclusion of mining, long-term impacts to springs from pit dewatering may be somewhat greater than the impacts of current operations, and monitoring and mitigation Measure W-1, approved in the 1998 ROD as Stipulation 010-4, would continue.

The trend of spring flows from 1998 to 2003 was reviewed and all but one spring was found to exhibit at least a slight decline in flow (HSI, 2003). The flow of Rattlesnake Spring increased slightly. Springs having a slight to moderate decline include Bunkhouse, Sheep Rock, Stepan Original, Stepan, and St. Paul. With springs at long distances from the pit, such as St. Paul and Sheep Rock springs, exhibiting as much or more relative decline in flow as those much closer to the pit, it was concluded that the drought had likely been the dominant factor leading to declining spring flows (HSI, 2003). From 1999 through 2003, annual precipitation recorded at the mine has averaged 2.59 inches below normal per year. Onsite precipitation monitoring for 1985 to 2005 averaged 13.89 inches. Precipitation was 10.9 inches in 1999, 11.3 inches in 2000, 9.58 inches in 2001,

11.61 inches in 2002, 13.09 inches in 2003, 13.89 inches in 2004, and 17.58 inches in 2005.

In summary, observations and measurements of springs performed for this analysis generally support the findings of the 1997 Draft EIS regarding impacts of pit dewatering, namely, that there may have been slight reductions in flow in some of the springs closest to the pit, and those with a potential hydrologic connection to the pit, including Rattlesnake Spring, Bunkhouse Springs, Stepan and Stepan Original Springs, Sunlight Spring and Arkose Valley Spring (the last two are covered by the West Waste Rock Dump Complex). However, no flow reductions have been found beyond those associated with drought. Additional spring flow reductions from pit dewatering are anticipated from the continuation of mining operations through Stage 5B.

Monitoring of springs for this analysis has not shown changes in water quality, but drought may have complicated interpretation of data (HSI, 2003).

4.3.2 No Pit Pond Alternative (No Action)

4.3.2.1 Impacts to Groundwater Quality and Quantity

4.3.2.1.1 Risk of Impacts to Groundwater Quality and Quantity in Permit Area

The most important issue related to pit reclamation at GSM is impact to groundwater. The 1997 Draft EIS, Chapter III, Section III.B.2 included a discussion of the regional and local groundwater resources. The 1997 Draft EIS, Chapter III, Section III.A also contained a description of the geochemistry of the ore and waste rock. In the 1997 Draft EIS, Appendix A, Table 1, groundwater quality in the backfilled pit was assumed to be an average of Ohio Adit, Stage 2 pit sump, Stage 3 pit sump, highwall seep, and water treatment plant feed water. In this SEIS, Section 3.3 presents updated geochemical information (Telesto, 2003c). In this SEIS, the projected pit water quality has been updated based on West Waste Rock Dump Complex pore water sampling and other geochemical samples taken from around the site that emanate from similar materials that may be undergoing similar processes as the pit backfill would. This water quality is worse than that used in the 1997 Draft EIS (see Table 4-5 in Section 4.3.3.1).

The 1997 Draft EIS, Chapter IV, Section IV.B relied on numerical groundwater model simulations of the local pit groundwater system conducted in 1995 as the primary basis for evaluating impacts to water quantity from pit dewatering (Hydrometrics, 1995). A detailed discussion of the groundwater model configuration and input parameters can be found in Volume 3, Appendix 4.7-1 of GSM's Permit Application (GSM, 1995b). Additional studies were performed for this SEIS, including a pit hydrogeology investigation (URS, 2001), a pit highwall seep study (Gallagher, 2003b), a new water balance model of the pit (Telesto, 2003a and 2006), an analysis of well and spring hydrographs (HSI, 2003), geotechnical assessment of backfill materials (Telesto, 2005), and an assessment of groundwater flow paths out of the pit (HSI, 2003 and 2006), and are discussed in Section 3.3.6.

Several factors of the pit reclamation plan that could affect groundwater resources include:

- Seepage from 13 percent of the East Waste Rock Dump Complex in Rattlesnake Gulch;
- Geochemistry of the backfill material and the effects on groundwater quality;
- Changes in water quality in the saturated zone in the backfill material;
- Amount of water entering the pit after closure; and,

- Ability to dewater the reclaimed pit.

4.3.2.1.1.1 Impacts from Waste Rock Dump Seepage

Under the No Pit Pond Alternative, up to 500,000 cubic yards (750,000 tons) would have been removed from the top of the East Waste Rock Dump Complex for the backfill sump (1997 Draft EIS, Chapter II, Section II.B.6.b; 1998 ROD). Based on the revised pit design in this SEIS under the No Pit Pond Alternative, 111,000 cubic yards (167,000 tons) of crusher reject would be placed in the pit, and no waste rock would be removed from the waste rock dump.

The 1997 Draft EIS, Appendix J evaluated waste rock dump water quality. A numerical model was developed and simulations performed to assess the ultimate extent and timing of impacts to water quality that could be caused by ARD from the waste rock dumps. The analysis for this SEIS performed a review of the methods and key parameters of the 1997 Draft EIS modeling, assembled updated information where available, applied methods of analysis consistent among the alternatives, and checked for differences in findings or conclusions that could affect the rating or selection among SEIS alternatives (HSI, 2003 and 2006).

4.3.2.1.1.1.1 Estimation of Long-Term ARD Production by Waste Rock Dump Complexes

The long-term quality of water discharge from the toe or base of a waste rock dump is controlled by the flow of water through the waste rock dump materials, the availability of oxygen, and the abundance of sulfide minerals and/or oxidation byproducts in the waste rock. These processes were described in detail in Appendix I of the 1997 Draft EIS. The focus of ARD impact analysis from waste rock dumps is two-fold:

- The hydrology of water infiltration through the waste rock, transport downward to the aquifer, and then down gradient through groundwater aquifers to the mixing zone boundary and receiving surface waters; and,
- The generation, transport and attenuation of the contaminants, principally acidity and metals, contained in the seepage.

The existing reclamation plan provides for covering all 2H:1V slopes on waste rock dump surfaces with 3 feet of cover soil having greater than 45 percent rock content and revegetation. This plan has not been approved for pit reclamation (DEQ and BLM, 2003). The reclamation cover is designed to limit water infiltration, thus minimizing the production and migration of ARD through the waste rock dumps.

As described in the 1997 Draft EIS, Chapter IV, Section IV.C, capping measures aimed at reducing water infiltration rates would reduce pollutant load in the short term. Based on the results from long-term ARD studies conducted at other sites, the rate of ARD generation may be reduced by reclamation, but cannot be eliminated (Bennett, 1997). For a range of potential infiltration rates the long-term ARD load would be expected to be similar. For this reason, ARD impact analysis focuses on the fate and attenuation of contaminants over a range of possible hydrologic conditions, assuming that ARD generation cannot be fully prevented.

4.3.2.1.1.1.2 Water Balance of the East Waste Rock Dump Complex

In the 1997 Draft EIS, Chapter IV, Section IV.B.1.a, three modeling approaches were used to provide an assessment of the water balance within reclaimed dumps at GSM:

- Hydraulic Evaluation Landfill Performance model (HELP) (Schroeder, et. al., 1994);
- A model by Schafer Limited (2001); and
- SOILCOVER model (Swanson, 1995).

These models use soil, climate, vegetation, and other information to establish a water budget. A variety of parameters considered in each model addresses the manner in which water on the waste rock dump surface can be removed by evapotranspiration and runoff. Water that is not removed by evapotranspiration and runoff is available to enter the waste rock dump interior by percolation.

All three model calculations in the 1997 Draft EIS were in general agreement and suggested that infiltration through the reclaimed dump surface would be on the order of 0.25 inch per year, which is about 1.7 percent of the 13.75 inches of annual precipitation incident to the dump surface area. The studies found that infiltration might be as high as 0.5 inch in wet years. Seepage from the East Waste Rock Dump Complex for 0.25 inch of infiltration was estimated to be about 10.5 gpm (Appendix J, 1997 Draft EIS).

Since the 1997 Draft EIS, updated estimates of infiltration on waste rock dumps at GSM became available with the completion of a technical report covering eight years (1992-2000) of hydrologic monitoring and reclamation of the West Waste Rock Dump Complex (Schafer Limited, 2001). Schafer Limited (2001) addressed ARD generation potential, oxygen and water movement, water balance, temperature, and water quality of the West Waste Rock Dump Complex. Although the West Waste Rock Dump Complex is not involved in any of the alternatives or actions in this SEIS, the technical analysis found it to be a surrogate for the East Waste Rock Dump Complex, thus providing a check on the modeling estimates done for the 1997 Draft EIS (Telesto, 2003c).

The average infiltration rate into revegetated portions of the West Waste Rock Dump Complex was 1.1 inches/year (Schafer Limited, 2001). This is greater than the HELP model study in the 1997 Draft EIS, which was 0.25 inch/year (best case) to 0.5 inch/year (expected case) on reclaimed surfaces, and less than 2 inches/year on unreclaimed surfaces (Schafer Limited, 2001). Not all of the infiltration measured in this study led to a continuing saturation of the waste rock dump materials, for the following reasons:

- Oxidation of pyrite consumes 3.5 moles of water for every mole of pyrite oxidized, chemically consuming water which therefore cannot flow out of the dump;
- Ferrihydrite, formed as a by-product of pyrite oxidation, has a greater capacity to retain water than the original pyrite;
- Heat produced by pyrite oxidation causes upward movement of air within the waste rock dump, particularly in winter. Cold dry air is pulled into the toe of the dump and is warmed as it flows through the interior, where it becomes water-saturated before exiting the top of the dump. Water vapor may also be expelled from the waste rock dump via latent heat transport (warm air is capable of greater moisture transport than cold air) and through water vapor transport. Evidence of heat and water vapor movement of these types has been seen at GSM; and,
- The percolation rate is lower than the saturated permeability, therefore not allowing saturated conditions to occur.

The average infiltration rate (1.1 inches/year) was a gross value, while the values used in modeling the East Waste Rock Dump Complex in the 1997 Draft EIS were net values (Schafer Limited, 2001). The difference was attributed to consumption of water by pyrite oxidation, water retention by ferrihydrite, and water loss from the waste rock dump via convective air flow. The processes described above should prevent flux of water through the pile for at least 20 to 50 years. The 1997 Draft EIS analysis in Appendix J provided modeling output graphs (Figures J-3 to J-24) which incorporated "best case", "expected case" and "worst case" ARD scenarios, with infiltration rates of 0.25, 0.50 and 2.0 inches/year, respectively. The 1997 Draft EIS modeling incorporated the range of infiltration measured and is considered a valid estimation of the expected long-term infiltration rate to groundwater through the East Waste Rock Dump Complex.

Beginning in November 2001, GSM sponsored another reclamation cover infiltration monitoring study within the East Waste Rock Dump Complex (Nichol and Wilson, 2003). Continuous monitoring of soil moisture at five different depths within the soil cover and upper portions of the waste rock (23 to 145 cm) indicated that the water movement was generally upward, and that net infiltration had not occurred during 2002. Additional monitoring was performed in 2005 (Shannon Dunlap, GSM, personal communication, 2006).

Evaluation of long-term infiltration estimates for soil covers at GSM found that approximately 0.25 to 0.5 inch/year of net infiltration occurred (Telesto, 2003e). For the purposes of assessing the middle to worst-case hydrologic impacts in this SEIS, a rate of 0.5 inch/year was determined to be the best estimate of net long-term infiltration for reclaimed waste rock dumps, with sensitivity evaluation up to 1.1 inches/year.

Impacts of ARD quality and quantity from the East Waste Rock Dump Complex were reevaluated in this SEIS and were similar to those identified in the 1997 Draft EIS. The following section addresses East Waste Rock Dump Complex ARD from the portion of the dump complex that is in the Rattlesnake Gulch drainage (Figure 3-7).

The methodologies used in the 1997 Draft EIS were reviewed and determined to be a reasonable and generally acceptable basis for the analyses and purposes of this SEIS, with some qualifications (HSI, 2003). These qualifications included:

- Although the methodology for the cell-by-cell ARD transport and attenuation modeling of the 1997 Draft EIS, Appendix J was described, a working version of the model was not available, so an alternate approach was used in this SEIS. Termed "pore volume attenuation," this approach is analogous to determining how much spilled milk (contaminants) a sponge (the aquifer) can absorb before dripping (releasing contaminants). In this methodology, the attenuation capacity (*i.e.*, the ability for a portion of the aquifer to retard or completely restrict the movement of chemical mass) of the aquifer flow path was quantified through geochemical estimations. Attenuation capacity is measured in terms of the mass of a chemical constituent per mass of the aquifer. Knowing the saturated water volume (*i.e.*, pore volume) per mass of aquifer and the concentration of constituents in the pore water, a calculation of how many pore volumes it takes to move an amount of constituents equal to the attenuation capacity was made;
- Only limited information on the calcite content of the Bozeman Group aquifer could be found, indicating calcite levels of less than 5 percent (the content used in the 1997 Draft EIS). The pore volume method eliminated the need for direct use of this parameter;
- The correlation of metals to predicted sulfate concentrations, as used in the 1997 Draft EIS analysis, was acknowledged to be simplistic, and not sensitive to differences among the alternatives. Again, the pore volume method eliminated the specific need for this correlation; and,
- This SEIS evaluation used updated values for some of the parameters in the fate and transport equations of Appendix J, and revised some of the 1997 Draft EIS predictions to be consistent with this information.

The 1997 Draft EIS, Appendix J, provided a discussion of the limitations and assumptions of the ARD fate and transport modeling. These also apply to this SEIS analysis, and can be summarized as follows:

- The model simplified complex hydrogeological and geochemical processes;
- There is some degree of error within the model predictions due to uncertainty in the model input parameters;
- The model is intended to characterize, compare, and contrast the types of possible impacts, not to accurately quantify those impacts; and,
- These impacts may or may not occur depending on future site-specific conditions such as long-term climatic conditions, infiltration rates, and oxidation rates, in addition to other physical conditions which are difficult to quantify such as moisture migration pathways, rate of groundwater movement and flow paths, and subsurface geochemical conditions.

A review was made of the key parameters that are required to be used in the hydrology fate and transport equations (HSI, 2003). Some of the parameters were estimated for the 1997 Draft EIS and were measured in studies specifically at GSM. For example, porosity was estimated to be 26 percent in 1997, but was measured at 4 to 10 percent in two recent studies at GSM. This SEIS evaluation focused on using a consistent approach in the sources and application of parameters among the alternatives. There was some emphasis on defining the "worst case" scenarios for the parameters to ensure that decision makers had information on the sensitivity of the estimates. Table 4-4 provides a comparison of the key modeling parameters from the 1997 Draft EIS, Appendix J, along with updated information and estimates used in this SEIS.

In the 1997 Draft EIS, Chapter IV, Section IV.B.1.a, the potential impacts from the East Waste Rock Dump Complex were evaluated for the Bozeman Group aquifer, upon which most of the waste rock dump rests. This was extended in this SEIS to include the portion of the East Waste Rock Dump Complex that overlies the Tdf/colluvial aquifer of Rattlesnake Gulch. Details of the updated ARD fate and transport model of the East Waste Rock Dump Complex conducted for this SEIS are presented in HSI (2003).

The total time for East Waste Rock Dump Complex seepage in Rattlesnake Gulch to travel through the Tdf/colluvial aquifer was not estimated in the 1997 Draft EIS. In this SEIS, the total time for East Waste Rock Dump Complex seepage from the portion in Rattlesnake Gulch to travel through the Tdf/colluvial aquifer was estimated at 80 to 190 years (HSI, 2003).

Table 4 - 4. Comparison of Key Parameters in ARD Modeling For the East Waste Rock Dump Complex over the Rattlesnake Gulch Drainage, EIS to SEIS[1]

East Waste Rock Dump Complex Parameter	1997 Draft EIS Appendix J	End of Stage 5B	Comments
Waste rock thickness	Up to 300 feet	Up to 300 feet	Approx. 222 acres of East Waste Rock Dump Complex would have up to 100 feet of waste rock removed in the backfill alternatives (about 33% of the volume)
Infiltration	0.25 - 2 inches/year	0.5 - 1.1 inches/year	Revised based on study of the West Waste Rock Dump Complex (Schafer Limited, 2001)
Recharge in undisturbed areas	1.5 inches/year	0.25 - 0.5 inch/year	Golder (1995a) water balance of Sunlight Block
Width of flow path	4,000 feet	3,300 feet	As mapped 2003
Thickness of flow path	Graded from 100 - 300 feet	150 feet	Based on observed depth of constituents below Tailings Impoundment No. 1
Length of flow path in Bozeman Group aquifer	13,200 feet	12,500 feet	Measured from toe of dump
Groundwater base flow rate in the Rattlesnake Gulch drainage	200 gpm	52 - 103 gpm	Flow rate reduced based on HSI 2003
Effective porosity	26%	4% - 10%	Herasymuik, 1996 and Schafer Limited, 2001
Specific retention	8%	5.5%	Schafer and Associates (1995) for the East Waste Rock Dump Complex
Permeability, Bozeman Group aquifer	$1.2x10^{-6}$ cm/sec (vertical); $2.5x10^{-4}$ cm/sec (horizontal)- est.	$2.5x10^{-5}$ cm/sec	Upper estimate of bulk permeability
Amount of calcite	5 percent	Not used directly	Used pore volume attenuation method
Sulfate concentration	30,000 mg/l	Not used directly	Used pore volume attenuation method
Mass of sulfide in dump	0.5 - 2 percent sulfide	Not used directly	Used pore volume attenuation method
Concentration of metals	Correlated from Schafer and Associates (1994)	Not used directly	Used pore volume attenuation method
Impacted aquifers	Bozeman Group aquifer	87 percent Bozeman Group aquifer, seepage of 8-18 gpm; 13 percent Tdf/ colluvial aquifer, seepage of 1-3 gpm	Based on updated aquifer mapping (HSI, 2003)
Thickness of unsaturated zone in Bozeman Group aquifer	200 feet	80 feet	

[1] *From HSI, 2003 as updated by the agencies.*

The 1997 Draft EIS, Chapter IV, Section IV.B.1.e predicted that the base flow captured below Tailings Impoundment No. 1 in Rattlesnake Gulch would be 200 gpm. The agencies assumed the 10.5 gpm of East Waste Rock Dump Complex drainage would report to the Bozeman Group aquifer and be attenuated. Based on this SEIS analysis, there is reduced flow in the Rattlesnake Gulch drainage of 52 to 103 gpm (HSI, 2003). One to three gpm of the East Waste Rock Dump Complex drainage would report to the Tdf/colluvial aquifer. Therefore, the 8 to 18 gpm drainage from the rest of the East Waste Rock Dump Complex that overlies the Bozeman Group aquifer is within the range of the 1997 Draft EIS analysis and mitigation Measure W-4, Stipulation 010-7 in the 1998 ROD. It is also within the contingency volume of water to be treated from the East Waste Rock Dump Complex under the No Pit Pond Alternative.

A Dynamic Systems Model (DSM) was utilized (Telesto, in HSI, 2003) to predict the water quality impact of seepage from the portion of the East Waste Rock Dump Complex expected to reach the Tdf/colluvial aquifer. Based on the expected average net infiltration rate of 0.5 to 1.1 inches/year on the East Waste Rock Dump Complex, the long-term seepage rate to existing aquifers after reclamation from the East Waste Rock Dump Complex was estimated at 7 to 17 gpm. The portion of this seepage expected to reach the Tdf/colluvial aquifer would be about 1 to 3 gpm. The GSM Attenuation Study (Telesto, in HSI, 2003) indicated that a solution of mixed Tdf/colluvial aquifer groundwater and East Waste Rock Dump Complex seepage would have 13 to 15 pore volumes of attenuation capacity in the Tdf/colluvial aquifer, at the net infiltration rate of 0.5 inch/year. Given the anticipated range of flows in the Tdf/colluvial aquifer (52 to 103 gpm), attenuation of exchangeable metals could be expected for 35 to 63 years. Some contaminants such as sulfate, arsenic, and zinc have little affinity for attenuation and would not be removed in transport. Because the water flow rate from net infiltration through the East Waste Rock Dump Complex is small compared to the entire flow through the aquifer, the time required to fill the attenuation capacity of the aquifer is directly proportional to the mass load into the aquifer. A net infiltration rate through the pile of 1.1 inches/year would increase the mass loading by roughly 2.2 times. Thus, the attenuation capacity would be exhausted approximately 2.2 times faster, and the resulting range would be from 16 to 29 years.

The results of the updated long-term fate and transport evaluation of the East Waste Rock Dump Complex led to the following conclusions about impacts to groundwater quality and quantity in the permit area:

- The 1997 Draft EIS said 10.5 gpm would seep from the East Waste Rock Dump Complex. Long-term hydrologic monitoring and reclamation studies at GSM indicate that the best estimate of average long-term net infiltration rate to reclaimed rock dumps is 0.5 inch/year,

with the gross infiltration rate of 1.1 inches/year, yielding seepage rates from the East Waste Rock Dump Complex of 11 to 25 gpm (Schafer Limited, 2001; Telesto 2003e). Eight to eighteen gpm would travel down the main waste rock flow path; and,

- Based on updated hydrogeologic data, the thickness of the unsaturated zone of the Bozeman Group rocks beneath the East Waste Rock Dump Complex is typically 80 feet, compared to the 200 feet used in the 1997 Draft EIS. This shortens the time for breakthrough of ARD to the Bozeman Group aquifer.

It is possible to estimate the rate at which pyrite and other sulfide minerals are oxidizing by monitoring the internal temperature of the dump (Harries and Ritchie, 1987). Monitoring conducted on the West Waste Rock Dump Complex showed that the unreclaimed portion of the complex had a higher average temperature than the reclaimed portion (Schafer and Associates, 1994). The data indicated that the cover provided no definitive control on oxidation rates (Bennett, 1997).

Water is consumed geochemically during the oxidation of sulfide minerals in the waste rock dump complexes. Additionally, the oxidation of sulfide minerals raises the internal temperature of the dumps and appears to produce a chimney-like effect where cool air is drawn in the sides of the waste rock dumps and hotter, moister air exits through the top. This effect ensures a continued supply of oxygen for sulfide oxidation, but also can act to remove water from the dump interior in the form of water vapor. As much as 5 inches of water per year were reported to be removed by this convective mechanism (1997 Draft EIS, Chapter IV, Section IV.B.1.a). To be more protective of groundwater quality, modeling for the 1997 Draft EIS and this SEIS assumed that no water was removed by this convective mechanism. The agencies expect that the convective mechanism would eventually stop and water would exit the dump as seepage.

4.3.2.1.1.1.3 Long-Term Monitoring and Mitigation for Unanticipated East Waste Rock Dump Complex Seepage

As pointed out in the 1997 Draft EIS, Chapter IV, Section IV.B.1.a, it is possible that ARD-contaminated groundwater could travel through high conductivity preferential flow paths down gradient from the East Waste Rock Dump Complex. In addition, the water infiltration rate through the waste rock dumps could be higher than estimated, resulting in a greater flow rate of ARD than anticipated. As a contingency, potential monitoring and mitigation measures to control and contain unanticipated ARD in groundwater under the No Pit Pond Alternative are required by Stipulation 010-7 that was approved in the 1998 ROD. Table 4-2 shows the water treatment plant was designed to treat up to 25 gpm of East Waste Rock Dump Complex seepage. Appendix B, Section 6.0 of the 1997 Draft EIS, contains a GSM commitment to further hydrogeologic investigation of the waste rock dump complexes to identify optimum monitoring sites and to aid in the

design of groundwater capture systems if needed as contingencies for waste rock dump seepage. In addition, GSM has committed to construct additional monitoring wells along the waste rock dump perimeters as part of the long-term monitoring plan. A final mixing zone compliance monitoring plan will include additional wells along the approved mixing zone boundaries as identified in consultation with DEQ. As a result of this SEIS re-evaluation, no additional mitigation measures are needed.

4.3.2.1.1.1.4 Summary of East Waste Rock Dump Complex Seepage Impacts to Water Quality and Water Quantity

No impacts to groundwater quality from the portion of the East Waste Rock Dump Complex in Rattlesnake Gulch are anticipated during active mining operations through Stage 5B. The 1997 Draft EIS predicted that groundwater under the East Waste Rock Dump Complex would first experience ARD impacts in 54 to 433 years. An updated evaluation in this SEIS of the 1997 Draft EIS modeling was conducted using combinations of middle to worst-case parameters. The updated modeling predicts that groundwater under the East Waste Rock Dump Complex would first experience ARD impacts in 33 to 72 years (HSI, 2003).

4.3.2.1.1.2 Impacts from Pit Seepage

4.3.2.1.1.2.1 Impacts to Water Quality

Water quality in the pit under the No Pit Pond Alternative would be characteristic of ARD, similar to that produced by mining operations. Only 111,000 cubic yards (167,000 tons) of crusher reject would be used to create the sump in the bottom of the pit. This sump would prevent a pond from forming in the bottom of the pit (Figure 2-3 showing pit after backfilling).

Acidic backfill in the sump could affect pit water quality. The 1998 ROD did not specify a source of backfill material. There are two potential on-site sources of suitable backfill material (GSM, 2002a). One possible source of material is stockpiled mixed waste rock that was originally intended for reclamation of the waste rock dump complexes. Mixed waste rock consists of both sulfide and oxide waste rock. Another potential source is crusher reject material, which is proposed for use by GSM. Due to the screening process, this material is fairly uniform in size, with an average size of 2 inches or smaller, which would provide a relatively high porosity. Testing of these backfill sources was performed by GSM for this SEIS under a sampling and analysis plan approved by the agencies (Telesto, 2003g, 2003h; GSM, 2003a). The acid-base accounting tests found that the mixed waste and crusher reject both had negative net neutralization potential (NNP). The mixed oxide material had a NNP of -12, and the crusher reject had a NNP of -113. A negative NNP indicates the amount of lime needed to neutralize acidity in the waste rock. These materials had no neutralization

potential and pH values from leaching tests ranged from 4.4 to 7.4. In a pit backfill setting, both materials would generate ARD. The pit produces water in pH ranges similar to those from the leaching tests. The agencies assume that crusher reject would not change the quality of water needing treatment.

The agencies considered the use of other rock materials for the sump and concluded that they would decompose or become cemented in the saturated zone relatively quickly and would be no better than the waste rock or crusher reject for use as sump material over time.

In the 1997 Draft EIS, Appendix A, Table 1, groundwater quality in the backfilled pit was assumed to be an average of Ohio Adit, Stage 2 pit sump, Stage 3 pit sump, highwall seepage, and water treatment plant feed water. Pit sump monitoring by GSM in 2002 and 2003 has provided water quality data for the pit waste rock (GSM, 2002a; Telesto, 2003a). In 2002-2003, field pH ranged from 3.6 to 5.7, TDS ranged from 13,000 to 28,000 mg/l, sulfate from 9,370 to 20,400 mg/l, and dissolved copper from 0.7 to 12.2 mg/l (GSM, 2003e, 2004b). Other dissolved metals were also elevated. GSM's experience with pit water has shown that regular pumping from the pit sump or well reduces water quality degradation, primarily by limiting contact time with waste rock. Some of the water quality data in this period may not be representative because GSM conducted field experiments involving additions of organic carbon to the pit sump (Shannon Dunlap, GSM, personal communication, 2003).

Under the No Pit Pond Alternative, regular pumping would remove pit water from the crusher reject sump and send it to the water treatment plant. Regular pumping would maintain the pit as a sink, with a cone of depression in the potentiometric surface centered on the pit, similar to that which presently exists (Figure 3-5 in GSM, 2002a). No impacts to groundwater or surface water outside the pit would be anticipated because groundwater would not flow out of the pit. This agrees with conclusions in the 1997 Draft EIS.

If ARD inflows to the pit exceed the expected rates or the quality changes, Measure W-6 approved in the 1998 ROD as Stipulation 010-9 would apply. This measure provides for a re-evaluation of the water treatment plant capacity 2 years prior to mine closure, with modifications to the existing plant, or new treatment processes added for specific facilities, as may be required. Increased flows to the pit are not expected, based on observations during underground mining at GSM.

4.3.2.1.1.2.2 Impacts to Water Quantity

The No Pit Pond Alternative, in the 1997 Draft EIS, Chapter IV, Section IV.B.6, considered impacts associated with pumping water from the pit sump and focused on the quantity of water to treat and discharge. A pit water balance model was developed with the information available at that time (Hydrometrics 1995), which accounted for total inflows and outflows (see 1997 Draft EIS, Table IV-5). That model found that complete dewatering of the pit to the projected 4,700-foot-elevation pit floor at that time would require removal of approximately 102 gpm. Consequently, the 1997 Draft EIS concluded that water treatment requirements would have been greater under the No Pit Pond Alternative as compared to the Partial Backfill Alternative at that time, which would have required treatment of 50 gpm (1997 Draft EIS, Chapter IV, Section IV.B.7.b).

Based on GSM's experience in dewatering the pit and a new pit water balance model, lower pit water inflows are projected for the No Pit Pond Alternative (Telesto, 2006). The new model was calibrated to pumping records and predicts that pit dewatering would require perpetual removal of about 25 to 27 gpm. The hydrogeologic and water balance studies performed for this SEIS have shown that most of the water enters the pit through seepage from the Corridor Fault and through other faults in the upper half of the pit (Gallagher, 2003b; Telesto, 2003a). Faults penetrating the lower portions of the pit do not yield as much water. The underground mine, which is approximately 250 feet (4,400-foot elevation) beneath the pit bottom has less than 5 gpm of inflow, based on visual observation during mining activities. Water was imported to maintain underground mining operations (HSI, 2003). Therefore, standard hydrogeologic modeling, which predicts that pit inflows would continue to increase as the pit deepens, does not apply. The new studies also found that most pit inflows were related to direct precipitation on the pit and that more water is lost through evaporation than was previously suspected. The amount of water lost as a result of being heated and expelled as steam or warm vapor from the reaction of sulfides with water and oxygen (sulfide oxidation) was not quantified.

As stated in Section 4.3.2.2.2.2, the agencies have concluded that maintaining the pit as a hydrologic sink under the No Pit Pond Alternative would provide almost complete control of the ARD produced by the pit at its source and eliminate the risk of water quality impacts outside the pit.

4.3.2.1.1.2.3 Summary of Pit Impacts to Water Quality and Water Quantity

The analysis of this SEIS generally supports the findings of the 1997 Draft EIS for the No Pit Pond Alternative, except that the long-term pumping rate would be from 25 to 27 gpm, instead of 102 gpm. The impacts to water quantity from the open pit after closure would likely be limited to possible reductions in flows of springs close to and hydrologically connected to the pit, *i.e.*, Stepan, Stepan

Original, Rattlesnake, and Bunkhouse springs, as a result of pit dewatering. Even if drought conditions have reduced pumping rate predictions, the water treatment plant would be built to treat the 102 gpm analyzed in 1997.

Because the pit would be maintained as a local groundwater sink and all pit water would be collected and routed to the water treatment plant before being discharged, no impacts to groundwater quality from pit outflows are anticipated long term.

Potential additional water quantity impacts from the No Pit Pond Alternative would likely be limited to possible reductions in the bedrock aquifer groundwater level. The groundwater level around the pit would be permanently drawn down. This is an unavoidable impact of controlling all groundwater flow out of the pit by maintaining the pit as a hydrologic sink. This could result in reductions of flows from springs around the pit as described in Section 4.3.2.2.1.2.

4.3.2.1.2 Risk of Violation of Groundwater Standards at Permit Boundary and Impacts to Beneficial Uses of the Jefferson River Alluvial Aquifer

4.3.2.1.2.1 Impacts from Waste Rock Dump Seepage

The Tdf/colluvial aquifer groundwater and the East Waste Rock Dump Complex seepage would migrate down gradient and mix with 99 gpm in the Jefferson River alluvial aquifer, the portion of flow within the GSM mixing zone. Following exhaustion of the attenuation capacity, the Dynamic Systems Model indicated that this mixed groundwater would not exceed groundwater quality standards for any of the metals and trace elements modeled (arsenic, cadmium, copper, nickel, selenium, and zinc) (HSI, 2003 and 2006). The predicted nickel concentration, ranging from 52 to 78 percent of the standard (0.1 mg/l), came closest to violating water quality standards (HSI, 2006). The evaluation indicated that the results were sensitive to the initial concentrations in the Tdf/colluvial aquifer and to the mixing rate. In comparison, the 1997 EIS, Chapter IV, Section IV.B.1.a found that long-term impacts to groundwater in the vicinity of the waste rock dumps would likely occur. The ARD fate and transport analysis provided in the 1997 Draft EIS, Appendix J indicated that full chemical neutralization of ARD would occur within 2,200 to 4,400 feet downgradient of the toe of the dump, within GSM's mixing zone. Thus, no impacts were predicted to groundwater outside the GSM permit boundary, or to the Jefferson River alluvial aquifer.

For this SEIS analysis, Telesto (2003c) evaluated data from West Waste Rock Dump Complex lysimeters, the 2002 to 2003 pit sump, highwall test pads, and springs and seeps. Because the pit would be backfilled with crusher reject, chemistry of porewater from the West Waste Rock Dump Complex was deemed to be most representative. Concentrations of constituents in the pit sump water

are comparable, if not slightly more concentrated, than the West Waste Rock Dump Complex pore waters.

The 1997 Draft EIS, Appendix J stated that uncertainties regarding the model inputs and the simulation itself allow for only a low to moderate level of confidence in the model predictions of specific ARD concentrations and travel times to various locations down gradient of the waste rock dumps. This limitation also holds for the updated evaluation presented in this SEIS. The assumptions are provided in Table 4-4.

The results of the updated long-term fate and transport evaluation of the East Waste Rock Dump Complex led to the following conclusions:

- Combining updated middle to worst case hydrogeologic parameters in the fate and transport equations, and in the absence of any attenuation, the total time of travel from the top of the East Waste Rock Dump Complex to the Jefferson River alluvial aquifer via the Bozeman Group aquifer was shortened from a range of 960 to 1,300 years in the 1997 Draft EIS to 245 to 575 years. The differences reflect updated information available since the 1997 DEIS: a) a lower effective porosity of the East Waste Rock Dump Complex; b) the thinner layer of unsaturated Bozeman Group aquifer beneath the dump; c) a smaller depth of mixing; and d) a slightly shorter length and width of the flow path within the Bozeman Group aquifer (Table 4-4);
- This SEIS analysis indicates that 1 to 3 gpm of the East Waste Rock Dump Complex discharge would enter the Tdf/colluvial aquifer in Rattlesnake Gulch. Using updated information and combining the worst case hydrogeologic parameters in the fate and transport equations, and, in the absence of any attenuation, the timeframe to breakthrough from the top of the East Waste Rock Dump Complex to the Jefferson River alluvial aquifer via the Tdf/colluvial aquifer in Rattlesnake Gulch is estimated to be 80 and 250 years for non-attenuated and attenuated contaminants respectively (HSI, 2003);

- The attenuation analysis in the 1997 Draft EIS, Figure 5-1 in Appendix B, which predicted that no ARD contaminants would move beyond 2,200 to 4,400 feet down gradient of the East Waste Rock Dump Complex, was checked with a straight pore-volume attenuation analysis based on the ARD Attenuation Study (Schafer and Associates, 1994). This approach indicates that 1.4 pore volumes of attenuation could be expected along the East Waste Rock Dump Complex flow path and that ARD breakthrough beyond the permit boundary could occur in the range of 280 to 700 years. Groundwater capture would be required to prevent migration beyond the permit boundary;
- Mitigation measures, including additional groundwater monitoring, capture and treatment at the East Waste Rock Dump Complex, were approved in the 1998 ROD and incorporated into the permitted mixing zone for the East Waste Rock Dump Complex. Mitigation Measure W-4, Stipulation 010-7 in the 1998 ROD, responded to the issue of potential ARD releases that are premature or have greater than expected flows. This measure requires monitoring of groundwater at the mixing zone boundary and establishment of additional capture wells as a contingency under the GSM operating permit; and,
- The volume of seepage from the East Waste Rock Dump Complex predicted in this SEIS is within the contingency volume identified in the 1997 Draft EIS for the water treatment plant.

4.3.2.1.2.2 Impacts from Pit Seepage

Table 4-5 compares the projected pit water quality for this SEIS and the 1997 Draft EIS to Montana Groundwater Quality Standards. Table 1 of Appendix A of the 1997 Draft EIS presented estimated groundwater quality in the backfilled pit. Water quality was based on an average of values from the Ohio Adit, Stage 2 pit sump, Stage 3 pit sump, highwall seepage, and water treatment plant feed water.

The No Pit Pond Alternative would provide almost complete control of pit discharges by maintaining the pit water level as close as possible to the 4,525-foot elevation. There would be no risk of violation of groundwater standards and beneficial uses in the Jefferson River alluvial aquifer.

4.3.2.2 Impacts to Surface Water Quality and Quantity

4.3.2.2.1 Impacts to Springs, Wetlands

4.3.2.2.1.1 Impact from Waste Rock Dump Seepage

As discussed in Section 4.3.1.1, no impacts to surface water quality and quantity from the portion of the East Waste Rock Dump Complex in Rattlesnake Gulch are anticipated during active mining operations through Stage 5B. Rattlesnake

Spring is already affected by naturally acidic groundwater. This SEIS analysis found that the East Waste Rock Dump Complex could contribute 1 to 3 gpm of ARD to Rattlesnake Gulch, which could affect water quality and quantity in the spring, possibly impacting its use for wildlife in the future. Mitigation of impacts to wildlife use of springs is required by Measure W-1, which was approved in the 1998 ROD as Stipulation 010-4.

4.3.2.2.1.2 Impacts from Pit Seepage

Impacts to springs outside the pit could be expected due to dewatering. This is similar to the conclusion reached in the 1997 Draft EIS, Chapter IV, Section IV.B.6.b. Stepan Spring has the greatest potential for reduced flows resulting from active pit dewatering. The Stepan Original Spring has less potential for reduced flows than Stepan Spring, but is more likely to have reduced flow than Rattlesnake Spring and Bunkhouse Springs. Rattlesnake Spring and Bunkhouse Springs have a potential for reduced flow, but any reduction in flow is expected to be minimal since no impact from pit dewatering has been documented, and these springs occur in the T/Q alluvial aquifer.

As stated in the 1997 Draft EIS, Chapter IV, Section IV.B.6, accurate quantification of incremental changes in spring discharge is not possible. It is anticipated that change in groundwater levels and impacts to spring flow would be somewhat greater under the No Pit Pond Alternative in this SEIS than the No Pit Pond Alternative in the 1997 Draft EIS due to the groundwater level being reduced from 4,700 to 4,525-foot elevation. Long-term potential to reduce spring flows would be as predicted in the 1997 Draft EIS. Mitigation of long-term impacts to downgradient springs requires a monitoring and spring enhancement plan. GSM maintains a spring monitoring program, including flow rates and water quality (GSM, 2002a), as required by Measure W-1 approved as Stipulation 010-4 in the 1998 ROD. This mitigation measure is adequate for the No Pit Pond Alternative.

The hydrograph analysis indicated that the groundwater cone of depression around the pit may not have reached equilibrium with the pit dewatering (HSI, 2003). The cone of depression can be expected to increase until equilibrium is achieved. This could take tens of years (HSI, 2003). Associated long-term impacts to springs could be somewhat greater than the operational impacts, as described in Section 4.3.1.2.1.

Table 4 - 5. Projected Pit Backfill Water Quality
Bolded numbers exceed the DEQ-7 standards (all in mg/L except pH, s.u.)

Constituent	SEIS Project Pit Backfill Chemistry Porewater Quality[1, 4]	1997 Draft EIS Pit Water Quality[2]	Montana Groundwater Quality Standards[3]
pH	2.23[5]	2.7	--
TDS	--	15,698	--
Calcium (Ca)	412	408	--
Magnesium (Mg)	530	1,199	--
Sodium (Na)	82	59	--
Potassium (K)	6	15	--
Sulfate (SO_4)	22,400	10,240	--
Nitrate+Nitrite as N (NO_3 + NO_2-N)	--	10.9	--
Aluminum (Al)	1,410	292	--
Arsenic (As)	**0.056**	**0.411**	.01
Cadmium (Cd)	**0.138**	**0.641**	.005
Chromium (Cr)	0.988	0.009	.1
Copper (Cu)	**55.88**	**75.9**	1.3
Iron (Fe)	**508**	**1,170**	.3
Lead (Pb)	0.01	**0.274**	.015
Manganese (Mn)	**37.78**	**126**	.05
Mercury (Hg)	0.001	0.000	.002
Nickel (Ni)	**13.03**	**5.84**	.1
Selenium (Se)	**0.0563**	0.015	.05
Silver (Ag)	--	0.000	.1
Zinc (Zn)	**21.33**	**90.4**	2

[1] *Concentrations are representative of the 75th percentile of the West Waste Rock Dump Complex pore water from Shafer Limited, 2001.*
[2] *1997 Draft EIS, Appendix A, Table 1.*
[3] *DEQ-7, February 2006 (note that iron and manganese have only secondary standards).*
[4] *SEIS data from Telesto, 2003c.*
[5] *Concentrations are representative of the 25th percentile of the West Waste Rock Dump Complex pore water from Shafer Limited, 2001.*

4.3.2.2.2 Risk of Violation of Surface Water Standards and Impacts to Beneficial Uses of the Jefferson River and Slough

The Montana Water Quality Act defines impacts to beneficial uses as impacts to public water supplies, wildlife, fish and aquatic life, agriculture, industry, livestock, and recreation. Known beneficial uses in the vicinity of GSM are shown on Map IV-2 of the 1997 Draft EIS, Chapter IV, Section IV.B. A review of beneficial uses relative to this SEIS evaluation follows.

4.3.2.2.2.1 Impacts from Waste Rock Dump Seepage

There are no close public water sources down gradient of the East Waste Rock Dump Complex. Domestic wells are located approximately 4,000 feet down gradient from Tailings Impoundment No. 2. The nearest downgradient surface water fishery is the Jefferson Slough. An area of GSM's property along the Jefferson River Slough is leased for cattle grazing. Acreage adjacent to the Jefferson Slough is being cultivated. There are no known industrial uses outside of the existing mine operations, or recreational beneficial use of the water resource that would be impacted by ARD from the waste rock dump complexes.

Because of limited surface water availability, springs at the mine site provide local wildlife habitat. The 1997 Draft EIS, Chapter III, Section III.B.2.d reported that Rattlesnake Spring, located approximately 3,100 feet down gradient of the East Waste Rock Dump Complex, was believed to receive flow from the Bozeman Group aquifer, potentially in part from the abandoned Rattlesnake Adit (Lazuk, 1996). At the surface, Rattlesnake Spring emerges from Tdf/colluvial aquifer (GSM, 1993; Golder,1995a). Bunkhouse Springs is approximately 3,400 feet down gradient of the East Waste Rock Dump Complex and occurs within the Tdf/colluvial aquifer.

The 1997 Draft EIS, Chapter IV, Section IV.E.1.a stated that, because these springs are used by wildlife for watering, impacts to wildlife associated with reduced water quality could occur, and that impacts are less likely to occur in Rattlesnake Spring, because of the ARD attenuation effects that are anticipated in the Bozeman Group aquifer. As discussed in Section 3.3.4 of this SEIS, the gravel deposits from which both of these springs discharge are extensively altered by ferricrete deposits indicative of prehistoric metal-rich groundwater transport and deposition of oxidation byproducts from sulfide mineralized zones in Bull Mountain. Rattlesnake Spring and Bunkhouse Springs have been acidic, with pH typically 4 to 5, and elevated metals concentrations for the monitoring record, going back to 1993 for Rattlesnake Spring. As indicated in Section 3.3.4, these springs have been affected by groundwater from naturally mineralized deposits.

This SEIS analysis found that the primary groundwater flow path from the East Waste Rock Dump Complex is through the Bozeman Group aquifer east of these springs (HSI, 2003). One to three gpm of seepage from the East Waste Rock Dump Complex could find its way into the Rattlesnake Gulch drainage and potentially impact Rattlesnake Spring. This could lead to further decline in pH and increases in metal concentrations. Impacts to Bunkhouse Springs would not be expected due to its location west of Rattlesnake Gulch.

In summary, the only beneficial use expected to be impacted by ARD migration down gradient of the portion of the East Waste Rock Dump Complex overlying the Tdf/colluvial aquifer in Rattlesnake Gulch, within the limits of the permitted mixing zone, is Rattlesnake Spring, which is used by wildlife. The spring has been acidic since monitoring began due to prehistoric deposition of oxidation byproducts within the aquifer, and any additional impacts to the Rattlesnake Spring may not be attenuated. Adverse impacts to other beneficial uses are not anticipated for the No Pit Pond Alternative. Mitigation of impacts to beneficial uses, namely, springs used by wildlife, within the mixing zone boundaries was required by Measure W-1, which was approved as Stipulation 010-4 in the 1998 ROD, that requires monitoring for changes in spring water quantity and quality.

The 1997 Draft EIS, Chapter IV, Section IV.B.1.a concluded that there would be no risk of violation of water quality standards and impacts to beneficial uses of the Jefferson River and Slough from ARD from the East Waste Rock Dump Complex under the No Pit Pond Alternative. This SEIS analysis supports that conclusion.

4.3.2.2.2.2 Impacts from Pit Seepage

Under the No Pit Pond Alternative through Stage 5B, water inflows to the pit are expected to be similar to present conditions averaging 25 to 27 gpm (Telesto, 2006). Groundwater inflows to the pit are not expected to increase even though the pit would be deepened from the 4,650-foot to the 4,525-foot elevation during Stage 5B. Monitoring has shown that pit inflows have not been increasing as the pit was deepened. The volume of water intercepted by the underground mine, which was 250 feet beneath the bottom of the pit, was typically less than 5 gpm, based on visual observation.

The agencies have concluded that the No Pit Pond Alternative would provide almost complete control of pit discharges by maintaining the pit water level as close as possible to the 4,525-foot elevation. Therefore, there would be no risk of violation of groundwater standards and beneficial uses in the Jefferson River and Slough.

4.3.2.3 Reclamation Plan Changes

The 1997 Draft EIS, Chapter IV, Section IV.C addressed the soil impacts that are common to all alternatives for the approved reclamation plan for the areas in the pit to be revegetated. The approved plan includes covering major benches that have sufficient width to allow machinery access with 2 feet of pH neutral, oxide, non-acid producing waste rock plus 2 feet of stockpiled soil for a total of 4 feet of growth medium (1997 Draft EIS, Chapter II, Section II.B).

GSM reclaimed the south portion of the West Waste Rock Dump Complex in 1998-2000 following the approved reclamation plan. The stockpiled oxide waste rock turned out to be slightly acid producing and had to be amended with lime. After the reclamation was completed, the agencies and GSM concluded that it would be better to come up with alternate materials if possible rather than amend the acidic waste rock with lime.

In the fall of 1999, GSM started reclaiming the West Waste Rock Dump Complex. Evaluations of the stockpiled oxide waste rock that was to be used identified that these materials were slightly acid producing.

As a result, GSM investigated alternative materials and proposed a modification of the approved waste rock dump reclamation coversoil system on August 22, 2000 (GSM, 2000). The proposed change was to place 3 feet of non-acid producing stockpiled soil over the acid producing sulfide waste rock rather than the previously approved coversoil system. The agencies evaluated the proposal and approved the change based on characteristics of the west side soils (DEQ and BLM, 2001).

The agencies did not approve the change for the East Waste Rock Dump Complex without further characterization of the east side soil stockpiles (DEQ and BLM, 2001a). GSM did further studies in 2001 and applied to modify the approved reclamation coversoil system for the East Waste Rock Dump Complex and the pit acres to be revegetated (GSM, 2001). GSM reapplied to place 3 feet of non-acid producing stockpiled soil over the acid producing sulfide waste rock rather than the approved 48-inch coversoil system. The agencies evaluated the proposal and approved the change (DEQ and BLM, 2002, 2003). For 2H:1V slopes, the agencies required that the east side soils be amended with rock to raise the coarse fragment content to greater than 45 percent.

The agencies did not approve the change for the pit areas to be revegetated, because of a shortfall of soils stockpiled on the east side and the amount of 2H:1V slopes that would be revegetated in a partial pit backfill alternative (DEQ and BLM, 2003). The changes in the coversoil system for the pit acres to be revegetated are evaluated in this SEIS.

The potential reclamation plan changes that would occur from the 1997 Draft EIS are as follows:

- Volumes of soil needed for reclamation capping;
- Composition and thickness of layers of soil cover;
- Amount of surface disturbance;
- Hazards to wildlife; and,
- Amount of unrevegetated acres.

Table 4-6 summarizes the volume of soil needed for pit reclamation in the alternatives. As of December 31, 2006, there were 2,236 total acres of disturbance within the GSM permit boundary (Table 2-1). Of that total, 1,072 acres have been reclaimed through 2006 (GSM 2006 Annual Report). The reclamation of all other associated disturbance (tailings ponds, facilities, roads, etc.) is not shown in Table 4-6. The associated disturbance around the pit was addressed under the 1997 Draft EIS and is common to all pit reclamation alternatives under consideration.

Table 4 - 6. Soils Comparison by Alternative for Pit Reclamation

Reclamation Plan	Additional New Pit Disturbance/ Pit Soil Cover Area (Acres)	Cover Soil Source	Cover Soil Required for Pit Closure Area (Cubic Yards)	Pit Acres Left Unrevegetated
No Pit Pond Alternative	0 / 53	Stockpiles	290,400	158
Partial Pit Backfill With In-Pit Collection Alternative	56/ 292[1]	Stockpiles plus soil borrow area	1,541,800	0
Partial Pit Backfill With Downgradient Collection Alternative	58 / 292[1]	Stockpiles plus soil borrow area	1,541,800	0
Underground Sump Alternative	0 / 52	Stockpiles	285,600	159

[1] Actual pit disturbance after reclamation would be 274 acres (218 plus 56 cast blasted). The 292 acres listed in the table under the partial pit backfill alternatives represent the total acres that need to be soiled and revegetated on 2H:1V slopes. The 2H:1V slopes increase the total acres by 18.

GSM has proposed a coversoil system consisting of 3 feet of soil for the pit acres to be revegetated in all alternatives. On 2H:1V slopes, the soil would be

amended with rock to raise the coarse fragment content to more than 45 percent as is approved for the East Waste Rock Dump Complex (GSM, 2002a).

GSM would either use borrow soil meeting the rock fragment requirement or blend coversoil with more rocky potentially acidic waste rock to increase the rock content from 30 percent to greater than 45 percent. The waste rock would have a net acid generating pH value greater than 4.5 to meet quality criteria approved for the East Waste Rock Dump Complex in Minor Revision 01-004 (DEQ and BLM, 2002 and 2003). A sample frequency of one sample per 10,000 tons would be used for soil testing to determine acid producing potential. GSM estimates that approximately 15 percent of the stockpiled waste rock would be used to raise the rock content of the calcareous coversoil to greater than 45 percent. Non-acid generating coversoil may be available from borrow areas.

GSM would test mixtures of the calcareous soils and the potential acidic waste rock materials to develop a recipe to produce the more than 45 percent rock content needed in the surface soils on 2H:1V slopes. GSM would verify that the resultant mixture would have a net neutralizing potential at a 3:1 ratio above the acid generating potential. After placement, GSM would verify net neutralizing potential again by sampling a 100 by 100-foot grid on the final surface. Verification of no impacts to plant growth with this plan would be addressed by a qualified third party technical specialist.

GSM would amend the surface soils with agency-approved organic amendments. GSM would try to achieve an average 1.0 percent organic matter content in the upper 4 inches of the replaced coversoils after organic matter addition. GSM would sample the organic matter content on a 100 by 100-foot grid on the regraded coversoil slopes. GSM has to document that the proper application rate has been calculated, applied, and incorporated as best as possible. GSM is concerned that, because of the 2H:1V slope, the organic matter would not be incorporated completely. Some would be lost to wind and water erosion. The agencies believe that some loss is acceptable. Any organic matter would enhance the establishment of microbes in the soil.

The 3-foot coversoil is intended to minimize infiltration into the waste rock by storing water within the cover material during wet periods and allowing water to be removed by evapotranspiration from the cover during drier periods. Cover thickness over about 18 inches in this climate would result in negligible increases in infiltration rate (Prodgers, 2000). The amount of water infiltrating through 18 inches or 3 feet would be similar and within the range used for water balance estimations (*i.e.*, 0.25 to 0.5 inch/year, or 2 to 4 percent of average annual precipitation) (Telesto, 2003a).

While the net infiltration through 18 inches or 3 feet is estimated to be similar, the durability of the covers may be different. Based on the experience with cover placement and maintenance on the West Waste Rock Dump Complex, it is

anticipated that the 3-foot coversoil with more than 45 percent coarse fragments would adequately resist erosion, particularly on slopes (DEQ and BLM, 2001a, 2003). This design has been approved for the East Waste Rock Dump Complex.

GSM has provided soil analyses for the proposed borrow site north of Tailings Impoundment No. 2 (GSM, 2002a). The agencies would require further testing to verify that the rock size and characteristics are adequate for use on 2H:1V slopes. An amendment to add rock fragments would be required if necessary. The agencies have concluded that the 3-foot coversoil system with the required rock content and characteristics approved for 2H:1V slopes on the waste rock dump complexes would be adequate to revegetate waste rock backfilled into the pit under any of the alternatives.

4.3.2.3.1 Surface Disturbance

GSM's permit area is 6,125 acres. GSM was permitted for 2,964 acres of disturbance (1997 Draft EIS, Table II-22) (GSM 2006 Annual Report). GSM's approved area for disturbance is 3,002.5 acres, which was acquired through minor revisions to the permit (GSM 2004 Annual Report). GSM is bonded for 2,619.8 acres of disturbance.

Table 2-1 compares the permitted disturbances at GSM with the proposed disturbances at the end of Stage 5B mining. GSM's 2006 actual disturbance was 2,236 acres. The numbers reported in Table 2-1 do not match the 1997 Draft EIS, Table II-22 because of updated mapping (GSM 2004 Annual Report). GSM has completed 1,072 acres of reclamation within the disturbance boundary. Table 2-1 details the completed reclamation.

The 1997 Draft EIS, Table II-22 estimated the pit disturbance area would be 254 acres. GSM's reclamation bond included covering with the 4-foot coversoil system and revegetation of 26 acres of pit area. The total pit disturbance area was permitted to be 336 acres of which 108 acres would be revegetated.

This SEIS estimates the pit disturbance area would be 218 acres. GSM proposes a 3-foot coversoil system and revegetation of 60 acres of the pit area. The total pit disturbance area, including the perimeter disturbance, would be 286 acres of which 128 acres would be revegetated. Seven acres in the pit area have been reclaimed with a 4-foot coversoil system. Under the No Pit Pond Alternative, GSM would revegetate another 53 acres (7 acres already reclaimed) with the 3-foot coversoil system, requiring 290,400 cubic yards of soil. None of the total 60 acres to be reclaimed would be on 2H:1V slopes and would not require rock amendments. Some soil placed inside the pit below the highwall is at risk of being lost or possibly mixed with acidic highwall rock as the pit highwall gradually sloughs to more stable configurations. The amount of soil that would be lost would be minimal. The soil loss would be an unavoidable impact of

revegetating areas next to the highwall. GSM has enough soil stockpiled to reclaim the pit acres.

4.3.2.3.2 Hazards to Wildlife

A total of 2,236 acres was disturbed as of 2006, and Stage 5B mining is not expected to result in additional disturbance (GSM, 2002a). No additional pit area disturbance would be created under this alternative. The pit would only be backfilled with 111,000 cubic yards (167,000 tons) of crusher reject. This would leave almost 1,775 feet of acid-producing highwall exposed. Because there would be no further pit surface disturbance, there would be no additional hazards to wildlife beyond those analyzed in the 1997 Draft EIS, Chapter IV, Section IV.O.3.e. If the pit cannot be dewatered for some reason and a lake forms in the pit, an additional hazard to wildlife would develop from exposure to contaminated water.

4.3.2.3.3 Total Remaining Unrevegetated Acres

In the 1997 Draft EIS, based on Chapter II, Section II.B.6.b and Table II-14, 228 out of 254 acres in the pit would be left unrevegetated. In this SEIS, of the 218 pit acres, 158 acres would be left unrevegetated. The difference is due to the reconfiguration of the pit since 1998.

4.3.3 Partial Pit Backfill With In-Pit Collection Alternative (Proposed Action)

4.3.3.1 Impacts to Groundwater Quality and Quantity

4.3.3.1.1 Risk of Impacts to Groundwater Quality and Quantity in Permit Area

4.3.3.1.1.1 Impacts from Waste Rock Dump Seepage

In the 1997 Draft EIS, Chapter II, Section II.B.7.b, 34,700,000 to 36,700,000 cubic yards (52,000,000 to 55,000,000 tons), or 30 to 32 percent of the total East Waste Rock Dump Complex volume would have been removed for backfill under the Partial Backfill Alternative. Approximately 20,500,000 to 22,000,000 cubic yards (30,800,000 to 33,000,000 tons) or 15 to 16 percent of the West Waste Rock Dump Complex would have been removed to cover the upper highwall. The West Waste Rock Dump Complex footprint would not have been reduced. In the 1997 Draft EIS, Chapter IV, Section IV.B.7, the East Waste Rock Dump Complex footprint would have been reduced by 82 acres.

In this SEIS, the partial pit backfill alternatives would remove 33,300,000 cubic yards (50,000,000 tons) or 33 percent of the total East Waste Rock Dump Complex volume at the end of Stage 5B. The footprint area would remain the same (GSM, 2002a), so the spatial dimension of potential impacts from the East Waste Rock Dump Complex would remain similar (Figure 2-6). To cover the upper highwall, 11,900,000 cubic yards (17,900,000 tons) of pit highwall material would be cast blasted to create the 2H:1V slopes. No West Waste Rock Dump Complex waste rock would be removed for backfill.

The topography of the East Waste Rock Dump Complex after mining Stage 5B is shown in plan and cross-section views on Figure 2-5, and the final configuration of the East Waste Rock Dump Complex after removing material for backfilling is shown on Figure 2-6.

Waste rock water quality would not change under the Partial Pit Backfill With In-Pit Collection Alternative. Impacts to long-term water quality under this alternative would be similar to those of the No Pit Pond Alternative, except that the East Waste Rock Dump Complex would achieve a saturated condition sooner, since the maximum thickness of waste rock would be reduced from 300 feet to 100 feet (Figure 2-6). Overall, the potential ARD impacts from the East Waste Rock Dump Complex under this alternative would be the same as under the No Pit Pond Alternative.

Since the thickness of the East Waste Rock Dump Complex would be reduced from approximately 300 feet to 100 feet in the thickest area, the time it would

take for the remaining waste rock to become wet to the point ARD exits the dump would be less. There would be less geochemical uptake of water, and the drying effect of convective air movement that occurs in waste rock dumps would be diminished. The average time until seepage begins would reduce from a range of 50 to 200 years (1997 Draft EIS, Chapter IV, Section IV.B.1.a), to 11 to 24 years (HSI, 2003: Table 6-2). This is based on a 100-foot thickness of waste rock. The downward migration of the 1 to 3 gpm seepage from the base of the East Waste Rock Dump Complex down the Rattlesnake Gulch drainage would be similar to that described for the No Pit Pond Alternative.

4.3.3.1.1.1.1 Long-Term Monitoring and Mitigation for Unanticipated East Waste Rock Dump Complex Seepage

Impacts to, and mitigation measures for, groundwater resources and beneficial uses of water would be the same as for the No Pit Pond Alternative.

4.3.3.1.1.1.2 Summary of East Waste Rock Dump Complex Impacts to Water Quality and Water Quantity

No impacts to groundwater quality from the portion of the East Waste Rock Dump Complex in Rattlesnake Gulch are anticipated during active mining operations through Stage 5B. The 1997 Draft EIS predicted that groundwater under the East Waste Rock Dump Complex would first experience ARD impacts in 54 to 433 years. An updated evaluation in this SEIS of the 1997 Draft EIS modeling was conducted using combinations of middle to worst-case parameters (HSI, 2003). The updated modeling predicts that groundwater under the East Waste Rock Dump Complex would first experience ARD impacts in 33 to 72 years. The water treatment plant has been designed to handle 25 gpm of seepage from the East Waste Rock Dump Complex as a contingency (1997 Draft EIS, Appendix A, Table 2-1).

4.3.3.1.1.2 Impacts from Pit Seepage

4.3.3.1.1.2.1 Impacts to Water Quality

Under the Partial Pit Backfill With In-Pit Collection Alternative, the pit would be backfilled from 4,525 feet to an average elevation of 5,400 feet. The pit highwall would be reduced to 2H:1V slopes by cast blasting and dozing. The backfilled pit would be graded at 4.3 percent to create a free-draining surface (Figure 2-4) and a 3-foot soil cover would be placed over the entire backfilled pit and reduced highwall and revegetated. Four wells would be installed through the backfill to the bedrock contact to maintain the pit as a hydrologic sink. As under the No Pit Pond Alternative, pit dewatering coupled with water treatment would be required.

The principal objective of this alternative would be similar to the No Pit Pond Alternative and would be to maintain the pit as a hydrologic sink and keep the

groundwater level as close as possible to the pit bottom elevation of 4,525 feet. If successful, this would control the ARD produced by the pit at its source and eliminate the risk of water quality impacts from pit groundwater seepage outside the pit.

The first 100 feet of crusher reject would be the same as for the No Pit Pond Alternative. Above this, approximately 33,200,000 cubic yards (50,000,000 tons) of waste rock from the East Waste Rock Dump Complex would be backfilled to an average 5,400-foot elevation. The backfill from the waste rock dumps would be trucked to the pit and end dumped.

The mechanics of end dumping and cast blasting would create segregated fine and coarse zones, based on observations at GSM from offloading a portion of the East Waste Rock Dump Complex in 1994. Each truck load would create a single segregated cell with larger material on the bottom and fines on top. There would be sorting within the dumping zone with fines higher in the section. The backfill timeframe allows rain events to redistribute fines in the pit creating less permeable lenses. The process of weight compaction and weathering would produce fines that could move into the lower portions of the backfill, including the crusher reject, which is the pumping zone.

Over time, the crusher reject would develop reduced permeability and may lose its ability to function as a sink to maintain collection of pit seepage. These effects would occur in any alternative that includes pit backfill, including the No Pit Pond Alternative. The effect would be more pronounced in the partial pit backfill alternatives because there would be a much greater volume of backfill, and backfill would consist of less uniformly graded material. Cast-blasting and dozing would create the 2H:1V final highwall slope. Slope breaks and surface water diversions off the slopes and backfill area are described in Section 2.4.3.5. Figure 4-1 shows the potential stratification of the pit backfill after pit backfilling. The final pit configuration after backfilling the pit is shown in Figure 2-4 in both a plan view and cross-sectional view.

In the 1997 Draft EIS, Appendix A, Table 1, groundwater quality in the backfilled pit was assumed to be an average of the Ohio Adit, Stage 2 pit sump, Stage 3 pit sump, highwall seepage, and water treatment plant feed water. A re-evaluation of the projected chemistry of pit water in the Partial Pit Backfill With In-Pit Collection Alternative was performed (Table 4-5) (Telesto, 2003c). If successful, dewatering would maintain the groundwater level in the backfill as close as possible to the 4,525-foot pit bottom elevation. The majority of the backfill would remain above the saturated zone, and geochemical reactions characteristic of an unsaturated environment would predominate. Oxidation of sulfide minerals in the unsaturated zone in the backfilled pit would proceed as in the reclaimed waste rock dump complexes, and the water chemistry would be similar to the pore water chemistry observed in the West Waste Rock Dump Complex (Table 4-5)

(Telesto, 2003c). The poor water quality would be expected to occur for hundreds to thousands of years.

Table 4-5 lists the estimated quality of pit water under the Partial Pit Backfill With In-Pit Collection Alternative, which corresponds to West Waste Rock Dump Complex pore waters (Telesto, 2003c). Because the geochemical processes in an unsaturated backfill scenario would be similar to those in the existing waste rock dumps, the water quality from the unsaturated pit backfill would be the same as in the waste rock dumps. The agencies expect that this water quality would develop in any waste rock used for backfill. Table 4-5 lists the water quality used in the 1997 Draft EIS and Montana groundwater quality standards for comparison.

The concentrations listed in Table 4-5 are intended as indicators of probable backfill water quality and the values listed are not intended to represent a chemically balanced water. The potential exists that some constituents could be slightly higher and others slightly lower than indicated. Placement of the waste rock material in the backfilled pit would result in low-pH, elevated metal-bearing groundwater from initiation of groundwater contact with the backfill for hundreds to thousands of years (Telesto, 2003c).

Jarosite is a byproduct of sulfide oxidation and can be characterized as a ferric-hydroxide sulfate mineral. In the unsaturated zone of the backfill, jarosite would be expected to continue to form because the geochemical processes in the unsaturated backfill would be no different than those in the waste rock dumps. In the saturated zone, assuming that oxygen flux is limited, jarosite would likely start to dissolve (Telesto, 2003c). As long as it is present, it would keep the redox potential (*i.e.*, the activity of electrons) in the range that would sustain low pH and high ferric iron activity and could promote the continued oxidation (*i.e.*, the loss of electrons) of pyrite. This process is exhibited in the Berkeley Pit (Maest, 2004). The pit is not anoxic, even below the chemocline, due to the presence of ferric iron. This shows that redox potential is not only a function of oxygen concentrations and that simply saturating a material to limit oxygen does not automatically raise the redox potential and limit metals solubility. There are other redox buffers in the system besides oxygen, including ferric iron ions.

In regard to the quantity of jarosite, it was observed to be prevalent in all samples that were examined through mineralogical analyses (Telesto, 2003j). Mineralogical analyses showed that of the clay sized particles, jarosite was present in major amounts (more than 50 percent by weight). Other lines of evidence suggest that it is prevalent also. For example, the consistency of waste rock samples evaluated using field methods suggested that a high clay content exists in the waste rock. Grain size distribution testing indicates that the clay-sized fraction is very small. Thus, the results of field-testing methods (*i.e.*, texture, amount of cementing) were influenced by the physical properties of jarosite by which the sieve analyses were not influenced (Telesto, 2003j). It is

important to note that jarosite dissolution is not instantaneous and jarosite will influence the redox potential of the pore water. This conclusion only relates to the continued geochemical reactivity of the saturated backfill. The unsaturated portion of the backfill would remain geochemically reactive in a manner consistent with the observations and measurements from the existing waste rock.

The predicted water quality of groundwater in a backfilled pit would fall within the range of concentrations found in ARD sources, such as the West Waste Rock Dump Complex pore water, the Midas Spring, the 2002-2003 pit sump, and the passivation test pads (Telesto, 2003c). GSM has experimented with passivation, which involves sealing pit walls to limit oxidation (GSM 2004 Annual Report).

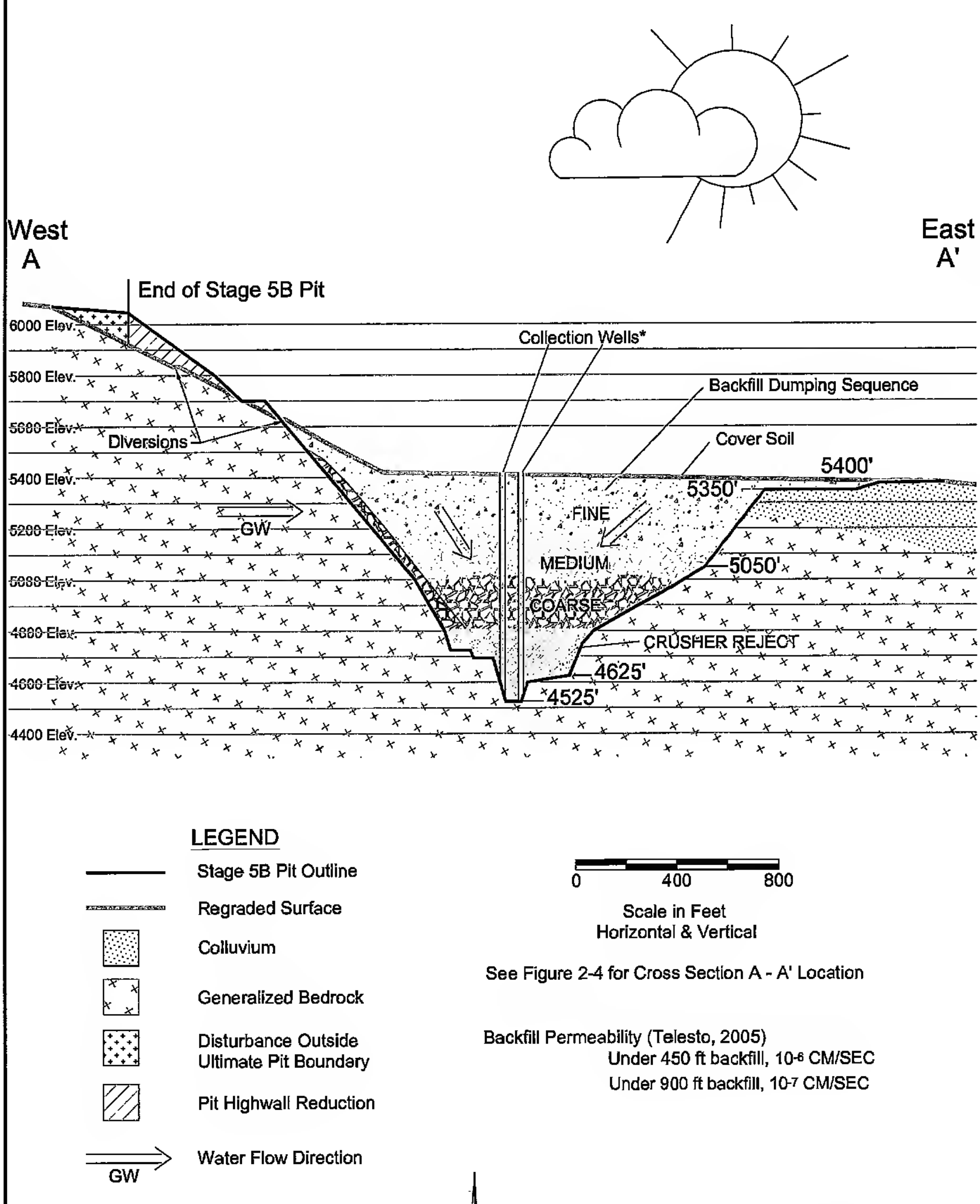
In particular, the pit sump water quality data have specific pertinence because the measured water quality from July 2002 to July 2003 documented the geochemical reactions occurring in a small scale version of the pit backfill (see Section 4.3.2.1.1.2.1). Waste rock that would have been directed to the East Waste Rock Dump Complex was allowed to fill in the bottom of the pit. A well was placed in the backfill and pumped almost continuously to maintain dewatering of the pit. Organic carbon (*e.g.*, methanol and other easily degradable forms) was injected into the pit sump material to attempt to limit the oxidation of sulfide material. This may have affected measured water quality. The concentrations of contaminants in the pit sump water are similar to the West Waste Rock Dump Complex pore water, even with organic carbon additions (Telesto, 2003c).

Based on conversations with agency representatives and consultants regarding the San Luis, Richmond Hill, and Butte underground mines and Berkeley Pit, none of the sites have an adequate period of record to make substantial conclusions on the ultimate water quality response to pit backfilling and pit/mine flooding (Gallagher, 2003c).

An independent evaluation of water quality in the Butte underground mines found that, while the Berkeley Pit water quality has not improved since the pit began filling in 1982, pH increased somewhat and cadmium decreased in the Kelley mine shaft, and dissolved copper decreased on the Belmont mine shaft, in correlation with the rising water levels (Maest, 2003). Other constituents experienced smaller reductions or no reduction in concentration since flooding began. Monitoring of the pit and underground water noted large variation in water chemistry throughout the underground workings. The period of record was not long enough to account for future geochemical processes that may reverse the observed improvements. Major elements and metals could remain elevated for an extended period of time, and it would be important to have control over water in the pit (*e.g.*, through draining via workings), so that treatment could be performed if required (Maest, 2003).

Water quality in the saturated portion of the backfill in the GSM pit would be expected to be acidic and elevated in metal concentrations. Based on the limited data reviewed in the Butte underground mines, which are not backfilled, it is possible that concentrations of some metals in the saturated portion of the backfilled GSM pit water would decrease "naturally" over the first five to ten years. Other metals and sulfate could remain elevated for an extended period of time. It is conceivable that ARD would be generated in the saturated backfill until the sulfides have reacted completely. Thereafter, the products of oxidation would be reduced and mobilized.

The pit backfill analog study conducted for this SEIS did not find any hardrock mine in the U.S. or Canada in which such a large pit was backfilled and allowed to become saturated with groundwater (Kuzel, 2003; Gallagher, 2003c). No long-term water quality monitoring records exist at the backfilled mines or flooded underground mines studied sufficient to indicate whether the reclamation goals at those mines were achieved.



See Figure 2-4 for Cross Section A - A' Location

Backfill Permeability (Telesto, 2005)
Under 450 ft backfill, 10^{-6} CM/SEC
Under 900 ft backfill, 10^{-7} CM/SEC

*Collection Wells Needed For Partial Pit Backfill with In-Pit Collection Alternative Only

Partial Pit Backfill Alternatives

CONCEPTUAL STRATIFICATION OF PIT BACKFILL

FIGURE 4-1

Figure 4-1.dwg

(Telesto - Feasibility Assessment, 2003e)

4.3.3.1.1.2.2 Impacts to Water Quantity

The potential impacts to water quantity by the open pit and reclamation alternatives in the 1997 Draft EIS were evaluated with a numerical groundwater model and a water balance study (GSM's Permit Application Appendix 4.7-1, Hydrometrics, 1995). In the 1997 Draft EIS, Chapter IV, Table IV-5, the water balance accounted for surface water recharge from snowmelt, direct precipitation, runoff, and groundwater inflow. The 1997 Draft EIS, Chapter IV, Section IV.B.2.b estimated the total inflow to the pit from surface water and groundwater sources would be 102 gpm. The 1997 Draft EIS, Chapter II, Section II.B.7.b indicated that backfilling under the Partial Backfill Alternative would reduce the amount of water needing treatment from 102 to approximately 50 gpm. Fifty-two gpm of storm water runoff would report off the reclaimed surface of the pit area or be lost to evapotranspiration.

In contrast, this SEIS concludes that backfilling would change the amount of water needing treatment from 25 to 27 gpm for the No Pit Pond Alternative to between 27 and 42 gpm for the Partial Pit Backfill With In-Pit Collection Alternative (Telesto, 2006). Seventeen gpm would report off the reclaimed surface of the pit area as storm water runoff or be lost to evapotranspiration (Telesto, 2003a). The ratio of water pumped for treatment compared to that which runs off is about the same as in the 1997 Draft EIS, with the difference in values between these studies attributable to the updated water balance calculations performed for this SEIS (Telesto, 2003a).

The water balance for this SEIS was based on calibration to 2003 records of pit water inflows and outflows. Average annual precipitation during that period has been reduced due to drought. The amount of water needing treatment could be somewhat higher in the future. The agencies assume that the total amount from the pit needing treatment would not exceed the 50 gpm indicated in the 1997 Draft EIS.

Cast blasting would increase pit disturbance by 56 acres to reduce the slope to 2H:1V. This could increase the amount of water infiltrating into the upgradient groundwater system, which would enter the Corridor Fault. This new disturbance would be covered with a 3-foot soil cover and revegetated. This soil cover would minimize infiltration, potentially balancing the increased water produced by 56 acres of new disturbance that could report to the pit.

4.3.3.1.1.2.3 Migration of Perched Groundwater

The potential for perched water migration across the pit was not analyzed for the Partial Backfill Alternative in the 1997 Draft EIS. The potential development of perched groundwater conditions in a backfilled pit was investigated for this SEIS (Telesto, 2003e). The development of perched groundwater conditions with

cross-pit migration hinges on whether a low permeability layer would exist from compaction or be created by oxidation byproducts below the level of the seepage. In the backfilled pit, the concern would be for the poor quality perched water to migrate into bedrock and avoid capture in the pit dewatering system.

Seeps have been identified in the highwall of the pit, and some are observed to flow continuously throughout the year, particularly those associated with the Corridor Fault (Gallagher, 2003b). If the pit is backfilled, these seeps would be buried, but would continue to flow, possibly creating perched water within the backfill materials and potential problems with localized small failures if they saturate the backfill and soil cover on the upper slopes.

Sulfide oxidation byproducts are colloidal in nature and effectively could seal pore space over time reducing permeability below seeps to $1x10^{-5}$ cm/sec or less (G. Furniss, DEQ, personal communication, 2004). As oxygenated water continues to emerge from the seeps and react with backfill, an impermeable layer of reaction products would spread outward across the backfill and would prevent the water from seeping downward in the backfill. Water could bypass the capture system and report to groundwater above the 5,050-foot elevation. This would be in addition to the 10 percent seepage from fractures assumed by the agencies below the 5,050-foot elevation.

For the Draft SEIS, hydraulic conductivity estimates for the backfill material ranged from 10^{-3} to 10^{-5} cm/s (Telesto, 2003e). Pit flow analysis conducted for the Draft SEIS predicts that hydraulic conductivity values of 10^{-6} cm/s or less would result in perching of groundwater within the backfill that would lead to horizontal, rather than vertical groundwater flow, thus permitting seepage to leave the pit without being captured by the wells (Telesto, 2003e).

Additional permeability testing of potential backfill material under simulated load conditions (such as that in a backfilled pit) was conducted subsequent to the Draft SEIS by Telesto (2005). The results indicate that, under 450 feet of backfill, the hydraulic conductivity can decrease to 10^{-6} cm/s, and that under 900 feet of backfill, the hydraulic conductivity can decrease to 10^{-7} cm/s (Telesto, 2005). This additional evaluation indicates that control of pit seepage with vertical wells would likely not be reliable. A different approach using directionally drilled dewatering wells would be no more effective than vertical dewatering wells because of the low hydraulic conductivity of the backfill and difficulty of predicting where groundwater flow paths could develop. If this alternative is selected, the agencies could bond for Measure 3, to identify secondary flow paths from the pit, and Measure 15a (see Section 4.8.2.1), to maintain operation of the Rattlesnake Gulch and Tailings Impoundment No. 1 pump back wells.

As noted in the pit backfill analog study completed for this SEIS, both the San Luis and Richmond Hill mines developed unexpected seepage of groundwater down gradient from the pits. This was unexpected at the Richmond Hill mine

because the pit was above the water table, so the source of the seepage was probably perched water in the backfill. The specific source of the seepage is not known but is suspected to be related to the pit (Gallagher, 2003c). The seep is impacted by ARD and must be captured and treated.

Permeability of the backfill could decrease over time due to compaction and weathering, as described in Section 4.2.2.1.2.

4.3.3.1.1.2.4 Summary of Pit Impacts to Water Quality and Quantity

As with the No Pit Pond Alternative, the Partial Pit Backfill With In-Pit Collection Alternative is intended to maintain the pit as a hydrologic sink and treat the groundwater in the permanent water treatment plant. If the Partial Pit Backfill With In-Pit Collection Alternative were to perform as intended over the long term, the impacts would be similar to the No Pit Pond Alternative.

4.3.3.1.2 Risk of Violation of Groundwater Standards at the Permit Boundary and Impacts to Beneficial Uses of the Jefferson River Alluvial Aquifer

4.3.3.1.2.1 Impacts from Waste Rock Dump Seepage

Impacts from the 1 to 3 gpm of seepage from the East Waste Rock Dump Complex in Rattlesnake Gulch would be the same as the No Pit Pond Alternative.

4.3.3.1.2.2 Impacts from Pit Seepage

If the groundwater capture systems described in Section 4.3.4.1.2.2 were able to be successfully operated over the long term, the impacts to groundwater in the Jefferson River alluvial aquifer would be similar to the No Pit Pond Alternative because the pit would be maintained as a hydrologic sink. There is a greater risk of groundwater excursions from the pit due to the potential for perched groundwater zones in the backfill as described in Section 4.3.3.1.1.2.3.

As a consequence of long-term failure of the dewatering system under this alternative, water would rise above the 5,050-foot elevation and reach a steady state at 5,260 (Telesto, 2003a) and discharge from the pit as it would under the Partial Pit Backfill With Downgradient Collection Alternative (see Section 4.2.2.9.2). Twenty-seven to forty-two gpm of pit seepage would reach groundwater and move down Rattlesnake Gulch toward the Jefferson River alluvial aquifer along with the 1 to 3 gpm of seepage from the East Waste Rock Dump Complex in Rattlesnake Gulch. A groundwater capture system like that for the Partial Pit Backfill with Downgradient Collection Alternative would be required to capture pit seepage, and impacts to groundwater in the Jefferson River alluvial aquifer would be the same as for that alternative.

4.3.3.2 Impacts to Surface Water Quality and Quantity

4.3.3.2.1 Impacts to Springs, Wetlands

4.3.3.2.1.1 Impacts from Waste Rock Dump Seepage

Impacts from waste rock dump seepage would be the same as the No Pit Pond Alternative.

4.3.3.2.1.2 Impacts from Pit Seepage

The 1997 Draft EIS, Chapter IV, Section IV.B.7.b concluded that spring flows outside the pit area under the Partial Backfill Alternative would be reduced because the pit would be maintained as a hydrologic sink. Impacts to the flow of springs and wetlands from pit dewatering under the Partial Pit Backfill With In-Pit Collection Alternative would be the same as the No Pit Pond Alternative. Under both, pit water elevations would be maintained as low as possible between 4,525 and 4,625 feet in elevation. As indicated in Section 4.2.2.5.2, under the Partial Pit Backfill With In-Pit Collection Alternative, groundwater levels in the backfilled pit could rise if operation or maintenance problems developed because of dewatering system failures. This could be caused by problems with well casings and pumps from settlement and corrosion of pumps and screens. The agencies would bond for additional wells to be installed to ensure that the water level would not rise above the 5,050-foot elevation. If the water level can be kept close to the 4,525-foot elevation, the impacts would be similar to the No Pit Pond Alternative.

The 1997 Draft EIS, Chapter IV, Sections IV.B.1.b and IV.B.7.b did not predict that, under the Partial Backfill Alternative, there would be any impacts to the water quality of springs from pit discharge. With the backfilled pit maintained as a hydrologic sink under the Partial Pit Backfill With In-Pit Collection Alternative, there also would be no water quality impacts to springs. However, if operational and maintenance problems led to loss of hydrologic control of pit groundwater allowing water levels to rise above the 5,050-foot elevation, ARD-affected water from the pit could reach existing springs or create new ones. In this case, Measure W-1 approved in the 1998 ROD as Stipulation 010-4, would be required to monitor, treat or augment spring discharge.

Measure W-1 was designed to respond to the identification and replacement of reduced discharge or reduced water quality at springs and seeps. It allows for establishment of a monitoring and sampling program frequent enough to detect spring responses to seasonal variations and pit dewatering. Mitigation includes improving collection and interception of spring waters, supplying replacement water, and enhancing water resources for wildlife and livestock. Measure W-1 would have to be modified to cover increased flows from springs under this alternative.

4.3.3.2.2 Risk of Violation of Surface Water Standards and Impacts to Beneficial Uses of the Jefferson River and Slough

4.3.3.2.2.1 Impacts from Waste Rock Dump Seepage

Impacts from the 1 to 3 gpm of seepage from the East Waste Rock Dump Complex in Rattlesnake Gulch would have similar impacts to those for the No Pit Pond Alternative described in Section 4.3.2.2.2.1.

4.3.3.2.2.2 Impacts from Pit Seepage

If the groundwater capture systems described in Section 4.3.4.1.2.2 were able to be successfully operated over the long term, the impacts to surface water in the Jefferson River Slough would be similar to the No Pit Pond Alternative because the pit would be maintained as a hydrologic sink. There is a greater risk of groundwater excursions from the pit due to the potential for perched groundwater zones in the backfill as described in Section 4.3.3.1.1.2.3.

As a consequence of long-term failure of the dewatering system under this alternative, water would rise above the 5,050-foot elevation and reach a steady state at 5,260 (Telesto, 2003a) and discharge from the pit as it would under the Partial Pit Backfill With Downgradient Collection Alternative (see Section 4.2.2.9.2). Twenty-seven to forty-two gpm of pit seepage would reach groundwater and move down Rattlesnake Gulch toward the Jefferson River alluvial aquifer along with the 1 to 3 gpm of seepage from the East Waste Rock Dump Complex in Rattlesnake Gulch. A groundwater capture system like that for the Partial Pit Backfill with Downgradient Collection Alternative would be required to capture pit seepage, and impacts to groundwater in the Jefferson River Slough would be the same as for that alternative.

4.3.3.3 Reclamation Plan Changes

4.3.3.3.1 Surface Disturbance

The 1997 Draft EIS, Chapter II, Section II.B.7.b estimated that all 254 acres in the pit would be reclaimed with the 4-foot coversoil system under the Partial Backfill Alternative. The Stage 5B pit disturbance area in this SEIS would be 218 acres. The pit would increase by 56 acres to 274 acres due to new haul roads and cast blasting the upper highwall. In this SEIS under the Partial Pit Backfill With In-Pit Collection Alternative, GSM would reclaim all 274 pit acres with the 3-foot coversoil system (Figure 2-4). About 239 of these acres would be on 2H:1V slopes and would require coversoil rock amendments.

Table 4-6 indicates that 1,541,800 cubic yards of soil would be needed to revegetate the pit disturbance in this alternative. GSM does not have enough

soil stockpiled to revegetate the pit acres. GSM has approved soil borrow areas from which to obtain soil. One source of cover material is the area northeast of the East Waste Rock Dump Complex, where soil had been obtained in the past. The haul for this material would include approximately 8,250 feet of flat grade and 1,920 feet of 10 percent grade for covering the lower portions of the backfilled pit. In order to haul material to the upper portions of the cast blasted backfill, the haul would consist of a total of 15,280 feet of flat grade and 8,955 feet of 10 percent grade. Additional haul roads would be required to haul soil to cover the reduced highwall.

Under Minor Revision 03-003, GSM is permitted an additional 8 acres of disturbance for a borrow area for the Tailings Impoundment No. 2 embankment construction. This additional area could be utilized for cover material (GSM, 2003c). Thirty-one acres of additional disturbance would be required. From the existing borrow area to the pit, the haul would include 2,700 feet of 6 percent grade and 3,250 feet of 3 percent grade. The haul route would be over existing roads for covering the lower portions of the backfilled pit. In order to haul material to the upper portions of the cast blasted backfill, the haul would consist of a total of 16,250 feet of 6 percent grade as shown on Figure 2-4.

4.3.3.3.2 Hazards to Wildlife

The total mine disturbance permitted is 3,002.5 acres (GSM 2006 Annual Report). GSM has indicated that 2,236 acres would be disturbed through Stage 5B (GSM, 2004 Annual Report). Additional pit disturbance of 56 acres would be created under this alternative. Even with the additional pit area disturbance, there would be fewer hazards to wildlife than under the No Pit Pond Alternative because the highwall would be eliminated. There would be no hazard to wildlife from exposure to acidic pit water.

4.3.3.3.3 Total Remaining Unrevegetated Acres

In the 1997 Draft EIS and this SEIS, no pit disturbance acres would be left unrevegetated in this alternative, except roads to the dewatering system.

4.3.4 Partial Pit Backfill With Downgradient Collection Alternative

4.3.4.1 Impacts to Groundwater Quality and Quantity

4.3.4.1.1 Risk of Impacts to Groundwater Quality and Quantity in Permit Area

4.3.4.1.1.1 Impacts from Waste Rock Dump Seepage

Waste rock removed for backfill material under this alternative would be the same as the Partial Pit Backfill With In-Pit Collection Alternative, except that no crusher reject would be used. The impacts of this alternative on groundwater resources and geochemistry of seepage from the East Waste Rock Dump Complex would be the same as the Partial Pit Backfill With In-Pit Collection Alternative except 1 to 3 gpm of seepage would travel down Rattlesnake Gulch with between 27 and 42 gpm of pit seepage (Telesto, 2003a, 2006).

4.3.4.1.1.1.1 Long-Term Monitoring and Mitigation for Unanticipated East Waste Rock Dump Complex Seepage

Long-term monitoring and mitigation for unanticipated East Waste Rock Dump Complex seepage would be the same as for the No Pit Pond Alternative and all other alternatives.

4.3.4.1.1.1.2 Summary of East Waste Rock Dump Complex Seepage Impacts to Water Quality and Water Quantity

Impacts to groundwater under this alternative would be essentially the same as the No Pit Pond Alternative and all other alternatives except 1 to 3 gpm of East Waste Rock Dump Complex seepage would migrate down Rattlesnake Gulch with between 27 and 42 gpm of pit seepage.

4.3.4.1.1.2 Impacts from Pit Seepage

The Partial Pit Backfill With Downgradient Collection Alternative would not maintain the pit as a hydrologic sink. Instead, the water table would be allowed to rebound and reach a steady state at the 5,260-foot elevation. Groundwater leaving the pit would be collected from wells located down gradient of the pit. At least 10 new monitoring wells and 26 additional groundwater capture wells may be required to intercept contaminated water. More wells may be needed based on hydrogeologic studies completed to identify flow paths. The wells would be installed in the T/Q alluvial and bedrock aquifers in drainages and along faults at various depths (Figure 2-7). This alternative would rely on a combination of partial attenuation, mixing with ambient groundwater, and collection to prevent

contaminated pit seepage from impacting groundwater outside of a permitted mixing zone.

For the Final SEIS, pit outflow was varied based on a revised pit water balance model (Telesto, 2006). The revised pit water balance model utilized new data collected by GSM subsequent to preparation of the Draft SEIS, and predicts a range of pit seepage values rather than a single estimate, as was reported for the Draft SEIS. The range of pit seepage values better represents the predictability of a natural system with numerous variables.

The conceptual model of pit inflow was reviewed and modified to include two baseflow components: baseflow that occurs beneath the Corridor Fault, and baseflow that occurs above and within the Corridor Fault (Telesto, 2006). The maximum baseflow above and within the Corridor Fault is estimated to be 30 gpm, based on the maximum potential recharge area for the pit. The baseflow from beneath the Corridor Fault was held constant at 2 gpm. For the Final SEIS, the total baseflow rate (*i.e.*, baseflow below, within, and above the Corridor Fault) was varied from 17 to 32 gpm. With this input range, the estimated rates of pumping for the Partial Pit Backfill With In-Pit Collection Alternative for the Final SEIS range from 27 gpm to 42 gpm, compared to 14.5 gpm for the Draft SEIS. The estimated rates of seepage from the pit for the Partial Pit Backfill With Downgradient Collection Alternative for the Final SEIS range from 27 gpm to 42 gpm, compared to about 16 gpm for the Draft SEIS.

Complex capture well systems would be required for this alternative. The fractured and faulted bedrock geology around the GSM pit may make it difficult to locate the seepage and to construct wells adequate to capture enough seepage. Collected water would be treated in the water treatment system and released in a percolation pond below Tailings Impoundment No. 2. Although some attenuation would help prevent impacts outside of the mixing zone in the short term, the available capacity is limited for effective, long-term attenuation along the primary pit outflow groundwater flow path. Attenuation would be limited because of historic flows of ARD along the flow path as indicated by ferricrete deposits in the area (HSI, 2003, 2006).

The geochemical conditions and evolution of groundwater quality in a backfilled pit were described by Telesto (2003c). The waste rock in the East Waste Rock Dump Complex has had 1 to 20 years to weather the sulfide by taking on oxygen and water. Wetting of the sulfide causes a heat-producing reaction, which drives the water off as steam. As a result, the waste rock is covered with oxidation byproducts, such as acid salts. Placing this weathered waste rock in the pit as backfill and allowing it to become saturated would mobilize these oxidation byproducts.

The waste rock placed in the unsaturated, oxidizing environment in the pit backfill would continue sulfide oxidation even though the chimney effect present in the

waste rock dump complexes would not be present in the backfilled pit. The accumulating groundwater in the backfill prior to pit outflow would have a chemical composition similar to that of the unsaturated zone with potentially higher concentrations due to the dissolution of the oxidation products. The oxidation of sulfide would be driven by both oxygen and ferric iron in the unsaturated zone above the water table in the pit and would be driven by ferric iron in the saturated zone.

Over the long term, the oxidation state of the deeper portion of the saturated backfill would decline due to the limited circulation of oxygen and reduction in the rate of sulfide oxidation (Telesto, 2003c). Until the existing amount of jarosite (ferric iron oxide) is dissolved and flushed from the system, it is likely that little change would be noticeable. Based on the water balance and rate of groundwater circulation through the pit, the pit discharge water quality until the backfill is saturated would likely resemble that listed in Table 4-5. As groundwater moves through the saturated backfill, water quality would gradually change. The time for circulation of one pore volume through the pit varies with the depth of the pit flowpath, with shallow groundwater requiring about 28 years and the deep pit flowpath requiring about 78 years (Telesto, 2006).

The ultimate quality of the groundwater discharging from the pit would be influenced by the rates of groundwater circulation through various depths of the pit backfill, ARD input from the unsaturated backfill via recharge, and the locations and elevations of the various pathways by which groundwater would leave the pit. The geochemical evaluation (Telesto, 2003c) indicated that production of ARD-impacted pit water would occur for hundreds to thousands of years.

Hydrogeologic evaluations indicated that most of the 27 to 42 gpm discharge from a backfilled pit would occur to the east, from the Sunlight/Range Front Fault and across and along the Corridor Fault from the 5,050 to 5,260-foot elevation (Telesto, 2003a). Some seepage would be expected to leave the pit through subsurface geologic structures directly connected to the deeper saturated portions of the pit backfill (see Section 3.3.7 for a flow path discussion).

The 1997 Draft EIS, Chapter IV, Section IV.B.7.b indicated that groundwater from a backfilled pit would exit through the colluvium at the east side of the pit (Hydrometrics, 1995). An evaluation of the groundwater flow paths through a backfilled pit was performed for this SEIS using a two-dimensional (cross-section) flow net analysis with existing hydrologic boundary conditions (Telesto, 2003e and 2006). Flow time through the pit would range from 28 to 78 years, from top to bottom of the pit, respectively. Most water that migrated through the deep portion of the pit would eventually flow out of the pit at a higher elevation (*i.e.*, out the Corridor Fault or similar flow path).

The flow net generated from the model indicated that precipitation recharge, which would migrate through the unsaturated portion of the pit, makes up approximately 25 percent of the total pit outflow. Another 25 percent of the pit outflow would contact a zone of waste rock that fluctuates between unsaturated and saturated conditions. Thus, roughly half of the pit discharge would be directly influenced by sulfide oxidation processes in the unsaturated zone of the backfill and would continue to transport ARD. The remaining half of the pit discharge will not likely contact unsaturated waste rock, but would be affected by the dissolution of sulfide oxidation products remaining in the deeper backfill. It is projected that it would be on the order of hundreds of years before the existing sulfide oxidation products are flushed from the upper portions of the backfill. Additionally, the remaining jarosite could maintain redox conditions that produce ARD beyond the hundreds of years time frame. (Telesto, personal communication, September 2004).

The combination of rinsing accumulated ARD products and continued oxidation in both the saturated zone and unsaturated zone would result in the discharge of low-pH, metal-bearing groundwater for at least hundreds of years. The water chemistry provided in Table 4-5 is appropriate for describing the probable composition of groundwater discharge from the pit for this period. Beyond the initial saturation period, while the quality of groundwater in the permanently saturated zone may be improved over that derived from the unsaturated zone, the overall quality of the actual discharge may or may not improve, as approximately 4 gpm or 10 to 15 percent of the pit discharge is derived from rain and snow melt recharge through the unsaturated backfill (Telesto, 2003e).

As documented in the 1997 Draft EIS, Chapter III, Section III.B.2.b, Table III-1, the quality of groundwater in the Tdf/colluvial aquifer is impacted by natural mineralization. Table III-1 indicated that the groundwater in Rattlesnake Gulch had a geometric mean pH of 4.3, sulfate of 731 mg/l, aluminum of 6.5 mg/l, copper of 0.43 mg/l, zinc of 0.54 mg/l, and nickel of 13.03 mg/l based on GSM monitoring wells PW-47, PW-63, PW-12 and PW-8 (shown on Figure 3-5). Much of the Tdf/colluvial aquifer has an alkalinity of 30 mg/l or less. The water quality data for the inputs to the pit flow path model were updated through 2004 and revised to use the appropriate sources (HSI, 2006).

The water balance indicated a pit discharge of from 27 to 42 gpm, having a pH of 2.2, sulfate of 22,400 mg/l, aluminum of 1,410 mg/l, copper of 55.9 mg/l, zinc of 21.3 mg/l, and nickel of 13.03 mg/l (Telesto, 2003a and 2003c). Groundwater discharge of a backfilled pit to the Tdf/colluvial aquifer in Rattlesnake Gulch would cause some additional deterioration of water quality, including increasing acidity and dissolved metals concentrations. Mixing the pit effluent of from 27 to 42 gpm with the expected range of 52 to 103 gpm of groundwater of upper Rattlesnake Gulch would result in an approximate average 7- to 15-fold increase in sulfate concentration and a 6- to 12-fold increase in copper concentration, assuming no chemical or physical reactions of these contaminants (HSI, 2006).

The basis of these estimates is provided in Table 4-7. Other metals would also increase in concentration. Upper Rattlesnake Gulch lies within GSM's permitted mixing zone. The mixing zone does not include the pit as a source of discharge.

The natural properties of the Tdf/colluvial aquifer to attenuate ARD contaminants from the additional chemical mass contributed to the existing mixing zone by groundwater discharge from the backfilled pit and the 1 to 3 gpm seepage from the East Waste Rock Dump Complex were evaluated (Telesto, 2003e). The analysis included acid/base reactions, silicate dissolution, sorption, ion exchange, oxidation-reduction reactions, and mixing.

Unlike the Bozeman Group aquifer, samples of the Tdf/colluvial aquifer do not include identified calcareous zones or carbonate cementation (SHB, 1981-1989; Golder, 1995). The lack of visual identification of carbonates indicates they constitute less than a few percent of the Tdf/colluvial aquifer material.

For the Final SEIS, samples of the Tdf/colluvial and Jefferson River alluvial aquifers were obtained from drilling performed in 2003-2005 and submitted for laboratory analysis of calcite. X-ray diffraction (XRD) and energy dispersive spectrometry (EDS) analysis, and scanning electron microscope (SEM) imaging were performed on nine samples from the saturated zone of the Tdf/colluvial and Jefferson River alluvial aquifers (Mogk, 2005). There was no evidence of the presence of calcite. The XRD results have a sensitivity level of about plus or minus 0.1 percent.

Table 4 - 7. Estimated Impacts to Groundwater Quality in the Tdf/Colluvial Aquifer From Pit Effluent

	Higher Estimated Groundwater Flow Rate In Tdf/Colluvial Aquifer SULFATE		Lower Estimated Groundwater Flow Rate In Tdf/Colluvial Aquifer SULFATE		
Discharge of Pit to Tdf	27	gpm	42	gpm	Telesto, 2006
Flow Rate in Tdf	103	gpm	52	gpm	Rattlesnake Wells 98-03
Mixed Rate	130	gpm	94	gpm	
Sulfate in Pit	22,400	mg/l	22,400	mg/l	Telesto, 2003c
Sulfate in Tdf	695	mg/l	695	mg/l	Avg. PW-8,11,12 63, 2003-05
Mixed Sulfate	5,203	mg/l	10,393	mg/l	
Change	**750**	%	**1500**	%	

	COPPER		COPPER		
Discharge of Pit to Tdf	27	gpm	42	gpm	Telesto, 2006
Flow Rate in Tdf	103	gpm	52	gpm	Rattlesnake Wells 98-03
Mixed Rate	130	gpm	94	gpm	
Copper in Pit	56	mg/l	56	mg/l	Telesto, 2003c
Copper in Tdf	2.129	mg/l	2.129	mg/l	Avg. PW-8,11,12 63, 2003-05
Mixed Copper	13.32	mg/l	26020	mg/l	
Change	**630**	%	**1,230**	%	

Limited neutralization potential could be provided by silicate dissolution for groundwater solutions with a pH below about 2.5 (Telesto, 2003c). The kinetics of acid neutralization by silicate dissolution are relatively slow. While this process is known to occur in the East Waste Rock Dump Complex, which is unsaturated and has relatively slow reaction kinetics, silicate dissolution is not expected to be an important factor for pit seepage in the Tdf/colluvial aquifer where groundwater flux is relatively rapid and contact time minimal (Telesto, 2003c).

Of the attenuation processes considered, ion exchange and sorption reactions are the ones likely to play a major role in attenuation of metals and acidity from GSM pit discharge. Based on the geologic descriptions of the Tdf/colluvial aquifer, it was assumed that the clay content included 1 percent smectite clay, 3 percent kaolinite clay, and 2 percent iron oxide cementation (Telesto, 2003e). A cation exchange capacity (CEC) was assigned for each of the clay and material types found in the Tdf/colluvial aquifer based on published data. CEC is the amount of exchangeable cations that a soil can adsorb at pH 7.0 (U.S. Department of Agriculture, 2003). CEC is a measure of the net negative charge of a soil and is related to the organic matter content and kind and amount of clay present in the soil. The effective CEC of the Tdf/colluvial aquifer was estimated to be 3.15 milliequivalents per 100 grams (HSI, 2003). This means that 3.15 milliequivalents (millimoles of a constituent divided by its valence state) of a constituent can become associated with 100 grams of clay particles in the Tdf/colluvial aquifer.

These calculations tend to overestimate the attenuation that would likely occur, because the calculations assumed that all of the constituents have an equal likelihood of sorbing to the available material and that the clays and iron oxides are uniformly distributed within the Tdf/colluvial aquifer and in full contact with the water. This is not the case in natural systems (HSI, 2003).

A mass balance calculation to determine the ion exchange capacity of the Tdf/colluvial aquifer was performed using the CEC value and the aquifer volumes presented above (Telesto, 2003e; HSI, 2003). The mass balance calculated the total mass of constituents that the aquifer could capture by the cation exchange

process and balanced that against the mass flux through the aquifer. The mass balance calculation was performed for two scenarios:

- Existing 103 gpm of Tdf/colluvial aquifer groundwater mixed with 1 to 3 gpm East Waste Rock Dump Complex drainage that would impact the aquifer. This is the condition that would prevail whether pit seepage occurred or not (such as in the No Pit Pond Alternative); and,
- Taking the 104 to 106 gpm of water and mixing the expected 27 to 42 gpm of pit seepage under the Partial Pit Backfill With Downgradient Collection Alternative.

As discussed in HSI (2003, 2006) and Telesto (2003a and 2003e), the 1 to 3 gpm of seepage from the East Waste Rock Dump Complex would be expected to occur prior to, or concurrent with discharge from the backfilled pit. Therefore, the waste rock dump seepage was factored into the baseline condition for Rattlesnake Gulch that would exist at the time the pit seepage would impact the Tdf/colluvial aquifer.

The Tdf/colluvial aquifer was divided into relatively uniform segments based on the detailed hydrogeologic data available from previous GSM studies (Golder, 1995; Hydrometrics, 1994, 1995, 1997; Keats, 2001, 2002). Rates of recharge to the aquifer segments were made to match the flow rates in the Tdf/colluvial aquifer indicated by the geometry, hydraulic gradient and physical properties of the aquifer. The final pit water balance model predicts the average outflow from the pit to be 27 to 42 gpm (Telesto, 2006). The analysis in the Draft SEIS indicated that, while a portion of pit outflows may exit the pit through other bedrock flow paths, this flow could rejoin the groundwater system of Rattlesnake Gulch, given the existing hydraulic heads and groundwater flow directions on the south side of the pit (Figure 3-6).

Dilution was accounted for by mixing the 27 to 42 gpm of pit effluent with the rate of discharge in successive segments of the Tdf/colluvial aquifer from the pit. Pit seepage would eventually mix with the 99 gpm flow of the Jefferson River alluvial aquifer within the GSM permit boundary.

A hydrogeologic characterization of the Tdf/colluvial aquifer was performed (Table 6-4 in HSI, 2003). A mixing model was developed (Telesto, 2003e). Recharge was added to mixing cells to balance the predicted range of groundwater flow within the aquifer (52 to 103 gpm) and a water chemistry of monitoring well MW-200, mid-way along the Tdf/colluvial aquifer flow path (Figure 3-5). As discussed in Section 4.3.2.1.1.1.2, the portion of the East Waste Rock Dump Complex overlying the Tdf/colluvial aquifer in Rattlesnake Gulch was predicted to contribute approximately 1 to 3 gpm of ARD seepage to groundwater in the range of 33 to 87 years in the future (HSI, 2003). This period overlaps the anticipated timing of discharge from the pit (21 to 61 years), thereby providing a

higher baseline concentration of these parameters than 2005 conditions (Telesto, 2006).

The downgradient groundwater collection for the Partial Pit Backfill With Downgradient Collection Alternative would be accomplished by a series of existing wells and at least 26 additional capture wells near or slightly west and south of the Rattlesnake Gulch interception wells (HSI, 2003). These include 10 within the throat of Rattlesnake Gulch, near the existing capture wells, and 16 on secondary bedrock pathways. The 16 capture wells on bedrock pathways included two at each of the eight bedrock structure locations identified in Section 2.4.4.3 and Figure 2-7. At least 10 new wells would be needed to intercept groundwater with an estimated average of 80 percent recovery efficiency across the 800-foot-wide Tdf/colluvial aquifer in the vicinity of the Rattlesnake Gulch interception wells. An evaluation of the Tailings Impoundment No. 1 south pumpback system indicated that contaminant capture efficiency can exceed 96 percent with intensive groundwater interception and monitoring (HSI, 2003, 2006). The agencies have concluded that 96 percent capture efficiency may not be achievable in the complex hydrogeologic setting in the secondary bedrock pathways, based on GSM's experience as described in Section 4.2.3.1.2. Based on their experience, the agencies believe a maximum capture efficiency of 80 percent per system is potentially achievable.

The pit would discharge under this alternative. Groundwater quality would likely deteriorate upgradient of the collection wells in an area where groundwater is already impacted by ARD from natural mineralization and by future seepage from the portion of the East Waste Rock Dump Complex that overlies Rattlesnake Gulch. The pit discharge of 27 to 42 gpm was not included in the 1998 Final EIS, Appendix 1 mixing zone analysis.

In contrast to the Partial Pit Backfill With In-Pit Collection Alternative, this alternative would allow the pit groundwater level to rebound and discharge down gradient. During backfilling over 3 years, groundwater could not be collected in the sump in the underground workings. Access to the underground would be lost as soon as backfilling operations were initiated. During and after backfilling, the groundwater level in the pit would slowly rise, saturating the backfill. Eventually, the groundwater within the backfill would establish a hydrologic steady state with the natural groundwater system around the pit. The 1997 Draft EIS, Chapter IV, Section IV.B.7.b predicted that the water table under the Partial Backfill Alternative would rise to the 5,050-foot elevation and begin to discharge to the Tdf/colluvial aquifer (Hydrometrics, 1995). The discharge rate estimated in the 1997 Draft EIS was 50 gpm. New information was analyzed for this SEIS to update this prediction.

Seepage of groundwater from the pit backfill would begin approximately 21 years after mining ceases, when the groundwater level reached the 5,050-foot elevation (Telesto, 2006). At this point, only about 26 percent of the backfill

would be saturated. A steady state pit groundwater elevation of 5,260 feet would be reached approximately 61 years following the cessation of mining, when 67 percent of the backfill would be saturated (Telesto, 2003a). The discharge rate from the pit would be 27 to 42 gpm.

As discussed in Section 3.3.6, a local groundwater divide exists near the eastern rim of the pit between wells PW-62 and PW-64 (Figure 3-7). From this point, the groundwater potentiometric gradient declines toward the hydrologic sink maintained in the pit to the west, and it declines abruptly to the Range Front Fault and the Tdf/colluvial aquifer to the east (see Figure 3-7). In a backfilled pit without water level control, groundwater levels are predicted to reach a steady state at the 5,260-foot elevation (Telesto, 2003a), which is between 68 and 115 feet above the groundwater divide which has existed during open pit mining. Although the Corridor Fault is believed to be relatively permeable, the pit backfill would continue to weather, forming oxidation byproducts and becoming less permeable over time. It requires a hydraulic head to move groundwater through the backfill to the fault to discharge from the pit.

Under the Partial Pit Backfill With Downgradient Collection Alternative, groundwater would saturate over 67 percent of the backfilled pit, and the water level would encounter the Corridor Fault at an elevation between 5,150 feet on the north side of the pit and 5,250 feet on the east side of the pit (Telesto, 2003a). Because the hydraulic head on the north side of the pit is higher than the water levels in the pit, the majority of the flow from the pit to the Corridor Fault is expected to occur near the east side of the pit.

Due to its large size and orientation, the Corridor Fault was identified in Section 3.3.7.2 as the primary pit flow path crossing through the pit and connecting with the Range Front Fault (HSI, 2003). The thick Quaternary gravel and debris flow deposits east of the Range Front Fault on the eastern rim of the pit, as mapped by Chadwick (1992), are hydrologically connected to the Tdf/colluvial aquifer in the upper Rattlesnake Gulch (URS, 2001; HSI, 2003). The majority of pit outflow is expected to migrate through the Corridor Fault and be conveyed to the Tdf/colluvial aquifer along and across the Range Front Fault (Gallagher, 2003a; HSI, 2003; Telesto, 2003a; URS, 2001).

As described in Section 3.3.1.4, the Tdf/colluvial aquifer is a buried gravel deposit forming a continuous groundwater pathway from the east edge of the pit and south through Rattlesnake Gulch, where it blends with the T/Q alluvial aquifer beneath Tailings Impoundment No. 1, reaching to the Jefferson River alluvial aquifer (HSI, 2003). The existence and extent of this flow path was mapped from geologic data in a number of detailed studies since 1982 (HSI, 2003). A map of the groundwater flow paths from the pit is provided in Figure 3-8 (HSI, 2003).

The 1997 Draft EIS, Chapter IV, Section IV.B.1.e predicted that the groundwater base flow captured below Tailings Impoundment No. 1 in Rattlesnake Gulch would be 200 gpm. New analyses based on additional information were conducted for this SEIS (HSI, 2003). The quantity of groundwater flow through the buried Tdf/colluvial aquifer in upper Rattlesnake Gulch north of Tailings Impoundment No. 1 has been estimated from existing data. The flow rate estimated with channel geometry data from Golder (1995a), geometric mean permeability from Golder (1995a) and SHB (1987) of 3.6 feet/day, and the new potentiometric map (HSI, 2003) indicates the ambient discharge would be a maximum of 103 gpm. The existing interception wells located in the upper portion of Rattlesnake Gulch above the Tailings Impoundment No. 1 produced a combined average of 50 gpm from 1998 through mid-2005 (Shannon Dunlap, GSM, personal communication, 2006).

4.3.4.1.1.2.1 Impacts to Water Quality

The Partial Pit Backfill With Downgradient Collection Alternative is the only alternative studied in detail that would not maintain the pit as a hydrologic sink. Overall groundwater capture efficiency of 96 percent or greater would be required to meet DEQ-7 water quality standards at the mixing zone boundary for the toxic and carcinogenic parameters modeled (HSI, 2006). The groundwater standard for iron, which is a secondary (harmful) standard would not be met at 96 percent capture efficiency (HSI, 2006, 2007). Groundwater discharging from the pit along the primary flow path would be captured by a series of wells in upper Rattlesnake Gulch and the existing Tailings Impoundment No. 1 South Pumpback system (Figure 3-5). Continued dewatering in the Rattlesnake Gulch drainage is an unavoidable impact of the groundwater capture system. Ninety-six percent capture efficiency may not be achievable, as described in Section 4.2.3.1.2. Based on their experience, the agencies believe a maximum capture efficiency of 80 percent per system is potentially achievable.

Degradation of groundwater quality would likely occur upgradient of the collection wells in an area where groundwater is already impacted by ARD from natural mineralization (see Table 4-7) and may eventually be impacted by the portion of the East Waste Rock Dump Complex in Rattlesnake Gulch. Although this area is within the permitted GSM mixing zone, pit sources are not included. As discussed below in Section 4.3.4.1.2,2 the water quality modeling and mixing evaluation indicated that degradation of groundwater would also occur in the Jefferson River Alluvial Aquifer at levels that would fail the nonsignificance criteria of ARM 17.30.715 (HSI, 2007),

The higher pit groundwater elevation under this alternative could lead to migration of ARD water from the pit along secondary flow paths in the bedrock aquifer and Bozeman Group aquifer where it is more difficult to detect and collect. As provided in mitigation Measure W-10 in the 1998 Final EIS, additional hydrogeologic studies and monitoring, along with at least 26 groundwater capture

wells, would be needed to attempt to comply with applicable standards. Some seepage would still escape the capture system. This SEIS suggests augmenting the existing monitoring well network with at least 10 additional monitoring wells.

The pit backfill analog study conducted for this SEIS did not find any hardrock mine in the U. S. or Canada in which such a large pit was backfilled and allowed to become saturated with groundwater (Gallagher, 2003c). No long-term water quality monitoring records exist at the backfilled mines or flooded underground mines studied sufficient to indicate whether the reclamation goals at those mines were achieved.

4.3.4.1.1.2.2 Impacts to Water Quantity

This alternative poses a greater risk than the Partial Pit Backfill With In-Pit Collection Alternative by creating new springs or having seeps impacted by ARD from the pit or increased discharges of ARD at existing springs around the pit area. Such new or increased sources of contaminants would be within GSM's established mine-wide mixing zone. Pit sources are not approved and would trigger a permitting review by the DEQ.

4.3.4.1.1.2.3 Summary of Pit Impacts to Water Quality and Quantity

The Partial Pit Backfill With Downgradient Collection Alternative does not maintain the pit as a hydrologic sink. It relies on the success of pumpback wells to capture and treat the groundwater in the permanent water treatment plant. Ninety-six percent capture efficiency is required, but may not be achievable, to avoid a violation of a water quality standard (HSI, 2006). Based on their experience, the agencies believe a maximum capture efficiency of 80 percent per system is potentially achievable.

4.3.4.1.2 Risk of Violation of Groundwater Standards at the Permit Boundary and Impacts to Beneficial Uses of the Jefferson River Alluvial Aquifer

4.3.4.1.2.1 Impacts from Waste Rock Dump Seepage

Impacts from 1 to 3 gpm of seepage from the East Waste Rock Dump Complex in Rattlesnake Gulch under this alternative would be the same as under the Partial Pit Backfill With In-Pit Collection Alternative.

4.3.4.1.2.2 Impacts from Pit Seepage

4.3.4.1.2.2.1 Impacts to Water Quality

The alternatives analyzed in the1997 Draft EIS did not include a scenario in which the pit would be permitted to freely discharge without being maintained as

a hydrologic sink. In addition, the 1997 Draft EIS, Chapter IV, Section IV.B.1.a found that there would be no impacts to the Jefferson River alluvial aquifer at any future time due to seepage from the waste rock dumps. The 1997 Draft EIS did not specifically analyze the rate of flow or attenuation potential of the Jefferson River alluvial aquifer.

Any uncaptured water originating from the pit would eventually migrate to the Jefferson River alluvial aquifer at the southern limit of the GSM permit area through the Tdf/colluvial aquifer and Quaternary alluvial aquifer occupying lower Rattlesnake Gulch, or the underlying Bozeman Group aquifer (Hydrometrics, 1994,1997; Keats, 2001, 2002). The Jefferson River alluvial aquifer consists of the stream deposits laid down by the Jefferson River. Based on the drill holes and monitoring wells installed by GSM in 2004 and 2005, the alluvial aquifer probably consists of two or more sand and gravel terraces which are hydrologically connected (Spectrum Engineering and Gallagher, 2005). The width of the Jefferson River alluvial aquifer is approximately 1,000 feet, from its northern limit to the closest point on the Jefferson River Slough within the GSM permit boundary (Figure 3-6). Geologic logs of GSM and private wells indicate that the saturated thickness of coarse sand, gravel and cobbles averages about 20 feet in the area along Interstate 90 and the Jefferson River Slough (HSI, 2003). Based on Jefferson River alluvial aquifer properties from previous studies, it is estimated that approximately 99 gpm of groundwater flows through the Jefferson River alluvial aquifer within the GSM permit boundary (HSI, 2003). The hydrologic and water quality parameters of the Jefferson River alluvial aquifer are provided in HSI (2003, 2006).

The water quality data for the inputs to the pit flow path model were updated through 2004 and revised to use the appropriate sources (HSI, 2006). New hydrogeologic and water quality data on the Jefferson River alluvial aquifer became available from GSM studies conducted after the Draft SEIS.

The Tdf/colluvial aquifer would have the theoretical capacity to attenuate 1.9 to 2.8 pore volumes of mixed pit discharge and ambient groundwater before the exchange capacity of the aquifer materials would reach a steady state with the groundwater (HSI, 2003). Since the 1 to 3 gpm of seepage from the portion of the East Waste Rock Dump Complex in Rattlesnake Gulch may reach the Tdf/colluvial aquifer first, little or no attenuation capacity may remain for the pit-impacted groundwater. With the 87.5 percent groundwater capture efficiency by the upper Rattlesnake Gulch collection system that would be required for this alternative, the Tdf/colluvial aquifer below this row of wells would only have 10 to 20 years of attenuation capacity (HSI, 2003, 2006). Since the exchange process is reversible, metals that were sorbed onto the aquifer materials could be remobilized by additional ARD seepage. Therefore, over the long term, the Tdf/colluvial aquifer would not attenuate ARD, and only mixing and collection would reliably serve to mitigate potential impacts.

A mass water balance was calculated using between 27 and 42 gpm of pit seepage, obtained from the revised pit water balance (Telesto, 2006), 52 to 103 gpm of ambient groundwater in Rattlesnake Gulch, and 1 to 3 gpm of seepage from the portion of the East Waste Rock Dump overlying Rattlesnake Gulch. A total of 80 to 148 gpm of contaminated groundwater would migrate down the Tdf/colluvial aquifer.

The analysis provided results for a range of capture efficiencies due to the variation in potential hydrogeologic conditions and operations. Bulk capture efficiencies over 95 percent have been estimated in an evaluation of cyanide capture below Tailings Impoundment No. 1 South Pumpback system for a single short period of time (Hydrometrics, 1994; HSI, 2003). This level of capture efficiency for a mixture of pit effluent and native groundwater would be less likely due to longer, more complex and heterogeneous flow paths along the Tdf/colluvial aquifer, and the potential for migration through adjacent bedrock aquifers. The lower capture efficiencies, a lack of long-term attenuation capacity in the flow paths (HSI, 2003, 2006), and the possibility of not identifying discrete flow paths (Keats, 2001) result in a greater risk of violating water quality standards at the mixing zone boundary. Keats (2001) concluded the second and third rows of pumpback wells were not completely capturing the seepage. Keats recommended treatment at the source area rather than adding pumpback wells. This was due in part to the difficulty in defining smaller scale contaminant pathways. Based on experience at GSM, capture efficiencies of 80 percent could be achieved for the individual groundwater collection systems included in Measure 15a (see Section 4.8.2.1).

This SEIS analysis indicates that the continued operation of the South Pumpback system would be needed to attempt control of contaminants from the tailing impoundment, naturally mineralized groundwater and potentially other future sources. Long-term downgradient monitoring would be required to assure continued compliance.

The primary pit flowpath model for the Draft SEIS predicted that two groundwater collection systems operating at 80 percent would achieve groundwater standards at the mixing-zone boundary. The dynamic systems model developed for the Draft SEIS predicted that two groundwater collection systems operating at 80 percent capture efficiency would result in an overall capture efficiency of 95 percent. This was based on an assumption of two capture systems in series without any intervening recharge occurring between the two capture systems. As a result of agency review and comments, the primary pit flowpath dynamic systems model was modified for the Final SEIS to better represent groundwater capture and recharge along the flowpath (HSI, 2006). The dynamic systems model modification accounted for natural recharge between the two systems, meaning that capture efficiency must slightly increase to capture sufficient contaminant mass so water quality standards are not exceeded. As a result, two capture systems operating at 80 percent capture efficiency give an overall

capture efficiency of approximately 92 percent. For the Final SEIS, the rate of seepage from the pit to the primary pit flow path was varied from 27 to 42 gpm, as predicted in the revised water balance model (Telesto, 2006).

The revised primary pit flowpath modeling conducted for the Final SEIS indicates that nickel especially, and cadmium, copper, arsenic, and zinc are the most critical parameters with respect to meeting groundwater standards in the Jefferson River alluvial aquifer at the mixing-zone boundary (HSI, 2006, 2007). Table 4-8 summarizes the DSM findings, and Table 4-2 depicts nickel concentrations under different groundwater capture scenarios and pit seepage rates.

Table 4-8. Ability to Meet DEQ-7 Groundwater Standards and Nondegradation Criteria in Jefferson River Alluvial Aquifer with the Partial Pit Backfill With Downgradient Collection Alternative for Selected Parameters.

Parameter	DEQ-7 GW Stds mg/l	No Capture of Pit Seepage	One Downgradient Capture System at 80% Efficiency	Two Downgradient Capture System, each at 80% Efficiency for a total of 92% (Measure 15a, Section 4.8.2.1)
Predicted Pit Seepage		27 – 42 gpm	27-42 gpm	27-42 gpm
Arsenic	0.01	DEQ-7 standard exceeded. Nondegradation criteria failed.	DEQ-7 standard met. Nondegradation criteria failed.	DEQ-7 standard met. Nondegradation criteria failed.
Cadmium	0.005	DEQ-7 standard exceeded. Nondegradation criteria failed.	DEQ-7 standard exceeded. Nondegradation criteria failed.	DEQ-7 standard met. Non degradation criteria failed.
Copper	1.3	DEQ-7 standard exceeded. Nondegradation criteria failed.	DEQ-7 standard exceeded. Nondegradation criteria failed.	DEQ-7 standard met. Nondegradation criteria failed.
Nickel	0.1	DEQ-7 standard exceeded. Nondegradation criteria failed.	DEQ-7 standard exceeded. Nondegradation criteria failed.	DEQ-7 standard exceeded. Nondegradation criteria failed.
Selenium	0.05	DEQ-7 standard met. Nondegradation criteria failed.	DEQ-7 standard met, Nondegradation criteria failed	DEQ-7 standard met. Nondegradation criteria met.
Zinc	2	DEQ-7 standard exceeded. Nondegradation criteria failed.	DEQ-7 standard met. Nondegradation criteria failed.	DEQ-7 standard met. Nondegradation criteria failed.

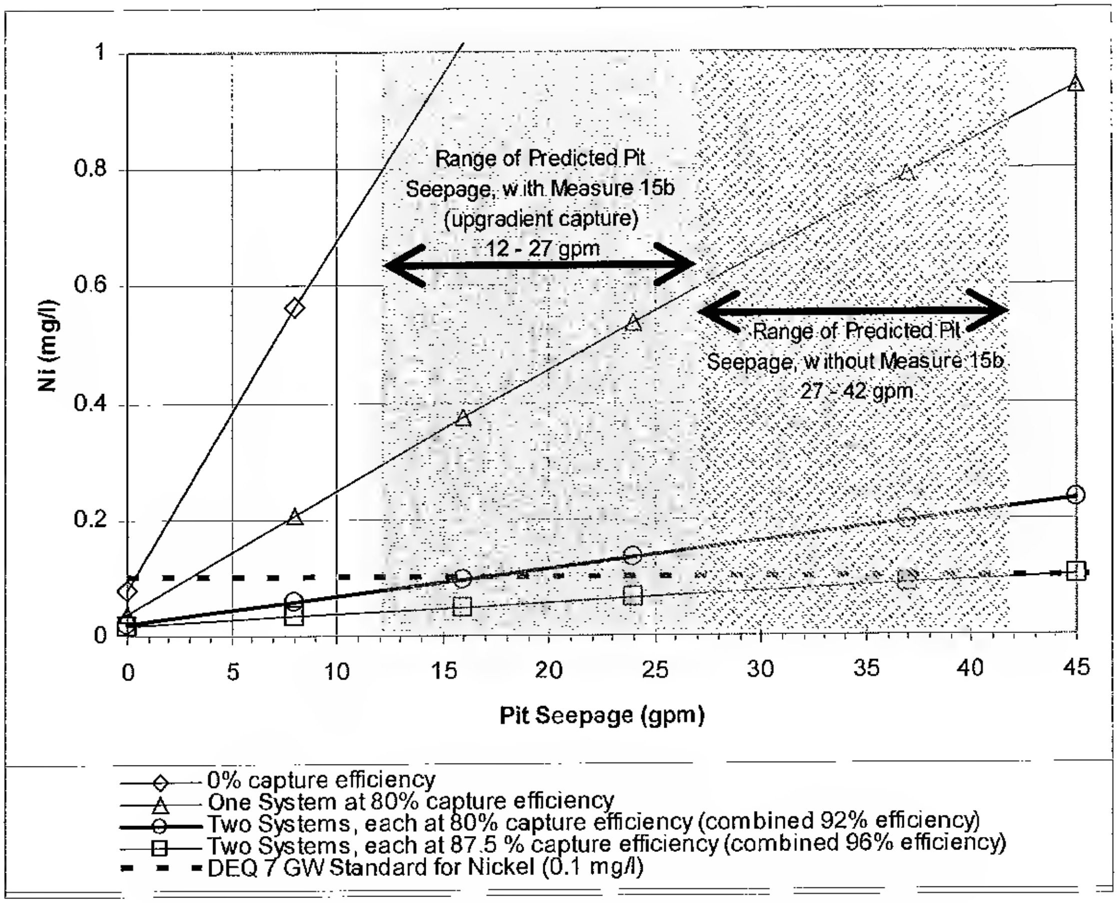


Figure 4-2. Predicted nickel concentration at the mixing zone boundary for various groundwater capture scenarios and pit seepage rates; the gray boxes represent the predicted ranges of pit seepage with and without upgradient capture.

The results of the primary pit flowpath modeling are summarized in the following points with respect to DEQ-7 groundwater quality standards and Nondegradation criteria (17.30.715 ARM). Mitigation measures discussed below are described in Section 4.8.2.1.

- If no pit seepage were captured, DEQ-7 groundwater standards for cadmium, copper, iron, nickel and zinc would be exceeded over the entire predicted range of pit seepage, and arsenic would be exceeded over a portion of the predicted range. Nondegradation criteria would fail for arsenic, cadmium, copper, iron, nickel and zinc over the entire predicted range of pit seepage, and selenium would fail over a portion of the predicted range.

- With one down-gradient collection system operating at 80 percent efficiency, DEQ-7groundwater standards for cadmium, copper, iron and nickel would be exceeded over the entire predicted range of pit seepage. Nondegradation criteria would fail for arsenic, cadmium, copper, iron, nickel and zinc over the entire predicted range of pit seepage, and selenium would fail over a portion of the predicted range.
- With mitigation Measure 15a (two collection systems, each operating at 80 percent capture efficiency), DEQ-7 groundwater standards for nickel and iron would be exceeded over the entire predicted range of pit seepage. Nondegradation criteria would fail for arsenic, cadmium, copper, iron and nickel over the entire predicted range of pit seepage, and zinc would fail over a portion of the predicted range.
- To meet DEQ-7 groundwater standards with only Measure 15a, the capture efficiency of individual capture systems would have to be approximately 87.5 percent each, resulting in an combined 96 percent capture efficiency (HSI, 2006). At 96% capture, nondegradation criteria for arsenic, cadmium, copper, iron and nickel would fail over the entire predicted range of pit seepage (HSI, 2007). Based on their experience, the agencies believe a maximum overall capture efficiency of 80% per system is potentially achievable (equivalent to 92% combined efficiency of two systems in mixing evaluation of HSI, 2006, 2007).
- With mitigation Measure 15a operating at a combined capture efficiency of 92% and mitigation Measure 15b (15 gpm of up-gradient groundwater capture) the DEQ-7 groundwater standard for nickel would be exceeded over a portion of the predicted pit seepage range (see Figure 4-2), and the groundwater standard for iron would be exceeded over the entire predicted range.
- With Measures 15a and 15b in place, additional capture systems would be required if pit seepage rates exceed 16 to 18 gpm. Implementing Measure 15c (near-pit downgradient groundwater collection) may further reduce pit seepage. However, for reasons discussed in Section 4.8.2.1 (and HSI, 2006), measure 15c would not be likely to reduce pit seepage sufficiently to meet DEQ-7 groundwater standards over the entire predicted range of pit seepage.

Based on the updated analysis for the FSEIS (HSI, 2006, 2007; Telesto, 2006), the agencies concluded that even with all identified mitigation measures (Section 4.8.2.1), compliance with DEQ-7 groundwater standards for metals in the JRA Aquifer could not be expected over the entire predicted range of pit seepage. Based on the water quality modeling and mixing evaluations (HSI, 2006, 2007) the agencies also concluded that degradation of groundwater would occur in the Jefferson River Alluvial Aquifer at levels that would fail the nonsignificance criteria of ARM 17.30.715. The consequences of failure of the groundwater capture system are discussed in Section 4.2.3.9.2.

Contingency measures for additional groundwater capture, such as Measure W-4 approved in the 1998 ROD as Stipulation 010-7, would be necessary for implementation of this alternative in the absence of the Tailings Impoundment No.1 south pumpback system. Measure W-4 requires monitoring of groundwater at the mixing zone boundary and establishment of additional capture wells as a contingency under the GSM operating permit. If the pit is allowed to discharge under this alternative, groundwater quality would likely deteriorate up gradient of the collection wells in an area where groundwater is already impacted by ARD from natural mineralization and would be impacted by seepage from the portion of the East Waste Rock Dump Complex that overlies Rattlesnake Gulch. The pit discharge of between 27 and 42 gpm was not included in the 1998 Final EIS, Appendix 1 mixing zone analysis.

Secondary groundwater flow paths were not identified in the 1997 Draft EIS. As the groundwater level rises in the pit backfill under this alternative to the 5,260-foot elevation, the agencies expect that 10 percent of the 27 to 42 gpm of pit discharge, or 2.7 to 4.2 gpm, would also migrate into fractures, faults and other geologic structures in the bedrock forming the pit highwall (HSI, 2003). Many of these structures provide the pathways for the seeps and springs discharging into the pit during mining (Gallagher, 2003b). The additional flow pathways are called "secondary" because their extent and continuity outside the pit may be limited or incompletely mapped, their hydrologic connection to existing surface water or groundwater features may be indirect, or their importance is inferred primarily by association with ferricrete deposits or high-yield wells, which provide indirect evidence of a pathway.

The Precambrian LaHood Formation, which is the bedrock hosting the ore body, has little to no natural attenuation capacity (Schafer and Associates, 1994). This rock, where mineralized, has produced acidity and metals naturally. Thus, any ARD migrating out of a saturated backfilled pit through bedrock structures would not likely be attenuated within the bedrock aquifer and may encounter mineralized zones, which could further deteriorate water quality.

Due to the uncertainty of secondary groundwater flow paths in the fractured bedrock, groundwater monitoring along known, hydrologically important geologic structures would be a component of this alternative. A review of the existing groundwater monitoring well network in the bedrock aquifer surrounding the pit was performed (HSI, 2003). A summary of the pertinent geologic structures, along with the degree of existing monitoring and recommendations for monitoring wells, is provided in Table 4-9. It indicates that at least 10 monitoring wells on geologic structures and other pathways would be required for this alternative. The potential locations of these wells are shown on Figure 2-7.

Groundwater capture wells on secondary pathways would be a contingency. The wells would not be installed until monitoring indicated a need. Based on previous studies of groundwater capture in bedrock (Hydrometrics, 1995) and experience

in drilling wells at GSM, it is estimated that at least two capture wells would initially be required for each structure with evidence of ARD migration. Testing and monitoring would be required to determine whether two wells achieved sufficient capture efficiency. More wells may be needed based on hydrogeologic studies.

Appendix B in the 1997 Draft EIS provided an analysis in support of a source-specific groundwater mixing zone for GSM. It included an assessment of groundwater capture in the fractured bedrock south of the pit around the West Waste Rock Dump Complex. This assessment concluded that capture efficiencies of 80 percent or greater were theoretically achievable in the fractured bedrock. A capture efficiency of 80 percent resulted in meeting all water quality standards for all metals except copper. An efficiency of 85 percent would result in compliance for copper. This is potentially achievable within the possible range of capture efficiencies. As noted in the 1997 Draft EIS, Appendix B, additional hydrogeologic characterization or capture wells may be required to meet these efficiencies.

Table 4 - 9. Anticipated Monitoring Sites for Groundwater Flow Paths out of a Saturated Pit

Flow Path[1]	Existing Monitoring Locations	Additional No. of Monitoring Wells	Comments
Primary Pit Flow Path			
Corridor Fault	None	2	Suggested locations are north of the key cut at the northeast corner of the pit rim
Range Front Fault	PW-4, PW-58, PW-59, PW-60	1	Suggested location is at or near mine parking lot, designed to intersect the fault
Tertiary Debris Flow Channel	PW-8, PW-11, PW-12, PW-63, MW-202, MW-200, Rattlesnake Spring, Bunkhouse Springs	0	Includes wells north of Tailings Impoundment No. 1 with the exception of the Rattlesnake Gulch interception wells
Secondary Pit Flow Paths			
Bozeman Group Aquifer	EFPB-21	2	Assumes EFPB-21 well would be available. Suggested locations are near the Old Assay Lab and the Buttress Dump

Sunlight Syncline	Stepan Spring, PW-17	1	Suggested location is east of PW-6 well near intersection of Sunlight Syncline and Telluride Zone
Sunlight PDZ	None	2	One suggested location is east of PW-6 well near intersection of Sunlight PDZ and Telluride Zone, a second location to the southeast
Telluride Zone	PW-6	0	Would be covered by wells for Sunlight Syncline and Sunlight PDZ
Latite Valley PDZ	PW-21 and Arkose Valley /Sunlight Springs Trench Drain	2	Suggest at least two additional monitoring wells to be located on the west ridge of pit near intersection of Latite Valley PDZ/Fenner Fault/Lone Eagle Fault
Fenner Fault	None	0	See Latite Valley PDZ
Lone Eagle Fault	None	0	See Latite Valley PDZ
St Paul Gulch PDZ	St Paul Gulch Spring	0	Spring monitoring should continue

[1] As modified from HSI (2003). See Figure 3-1 for fault locations and Figure 2-7 for monitoring well locations.

4.3.4.1.2.2.2 Impacts to Water Quantity

Appendix B and Appendix L of the 1997 Draft EIS evaluated groundwater capture efficiency from fractures in the bedrock aquifer using a flow rate consisting of 12 gpm of ambient groundwater flux plus 5 gpm of net seepage to groundwater from the West Waste Rock Dump Complex, for a total of 17 gpm flux at the capture wells. This SEIS reviewed the 1997 Draft EIS and applied this evaluation to the capture of seepage from a backfilled pit with downgradient collection. The rate of groundwater flux through secondary bedrock flow paths (faults, fractures and other geologic structures) from a backfilled pit not maintained as a hydrologic sink was estimated to be roughly 10 percent of the total pit outflow of 16 gpm, or 1.6 gpm, based on best professional judgment. The SEIS analysis of the groundwater impacts from a backfilled pit with downgradient collection found that an additional 1.6 gpm could be expected at downgradient capture wells in the bedrock aquifer. This additional flow is relatively minor and is adequately encompassed within the range of variability inherent in the capture analysis of the 1998 Final EIS.

The Partial Pit Backfill With Downgradient Collection Alternative would result in 1.6 gpm of pit seepage along secondary flow paths around the pit due to the higher hydraulic head in the pit relative to the groundwater elevations surrounding the pit (HSI, 2003).

Following implementation of the Partial Pit Backfill With Downgradient Collection Alternative, the presence of new or increased pit seepage would be determined through review of monitoring results and trends in conjunction with other relevant information. Evidence of both increased quantity and/or decreased quality of groundwater seepage or existing springs could trigger an agency review of the need for an MPDES permit or permit modification and applicability of Effluent Limitation Guidelines.

Measure W-10, Stipulation 010-13 in the 1998 ROD, would be modified to include additional hydrogeologic studies and monitoring, along with groundwater capture wells east and south as well as west of the pit. Wells installed as a result of these studies would attempt to offset this problem of complying with applicable standards. Existing and additional conceptual monitoring well locations are suggested in this SEIS for bonding purposes (Figure 2-7 and Table 4-8). More wells would be needed due to the uncertainty of hitting groundwater flow paths.

Secure funding and infrastructure are required to collect and treat contaminated water in perpetuity. The principal consequence of failure of this alternative would be undetected or uncaptured discharges of ARD-impacted groundwater from the backfilled pit, which could adversely impact springs and beneficial uses of the Jefferson River alluvial aquifer. In the worst case with no pumping and collection of pit seepage, 16 gpm could reach the Jefferson River alluvial aquifer compared to no discharge expected in the alternatives that maintain the pit as a hydrologic sink.

4.3.4.2 Impacts to Surface Water Quality and Quantity

4.3.4.2.1 Impacts to Springs, Wetlands

4.3.4.2.1.1 Impacts from Waste Rock Dump Seepage

The impacts to springs and wetlands from waste rock dump seepage would be the same as the No Pit Pond Alternative.

4.3.4.2.1.2 Impacts from Pit Seepage

The 1997 Draft EIS, Chapter IV, Section IV.B.1.b concluded that some spring flows could be reduced because the pit would remain a hydrologic sink. The potential impacts to springs discussed under the No Pit Pond and Partial Pit Backfill With In-Pit Collection alternatives in this SEIS were also primarily related to diminishing spring flows with the pit maintained as a hydrologic sink. Under

the Partial Pit Backfill With Downgradient Collection Alternative, the pit would not be maintained as a sink. After approximately 123 years, groundwater in the pit would reach steady state with the surrounding groundwater system at an elevation of 5,260 feet (Telesto, 2003a). Under this alternative, the potential adverse impacts to springs would be related to an increase in quantity of flow and a decrease in water quality. Of the eight bedrock geologic structures identified as possible groundwater flow paths from a saturated pit, six are associated with springs or seeps (see Section 3.3.4, and HSI, 2003). Figure 3-5 shows all the springs around the pit.

Stepan, Stepan Original, Sunlight, Arkose Valley, and Midas springs are situated around the pit and are associated with faults or synclines, or with abandoned mine Adits, which are also on geologic structures. Rattlesnake, Bunkhouse and North Borrow springs are situated where discharge from a backfilled pit along the primary flow path could adversely impact the quality and quantity of these springs prior to the point of initial capture in Rattlesnake Gulch. The former Midas Spring is a seasonal discharge that occurs in an active slump area (DEQ and BLM, 1998) and was buried by the East Waste Rock Dump Complex (See Section 4.2.1.5.2.1.6). The source of the spring is uncertain but may originate from the abandoned Midas Adit. It may become acidified within the adit and by contact with waste rock in the dump. It is captured and conveyed to treatment.

Some springs, including Rattlesnake, Bunkhouse, Stepan, and Stepan Original have been slightly to strongly acidic and contain some elevated metal concentrations (Table 3-1). This water quality is due to natural mineralization, but possibly affected by historic underground mining. These springs also have ferricrete deposits, which are indicative of long-term deposition of iron and other minerals by groundwater discharge before mining began in the area (HSI, 2003).

In addition, potential impacts could occur to springs having better water quality than that located in the pit, including the Sunlight and Arkose Valley springs. These two springs are on the Latite Valley PDZ, a geologic structure that has four of five indicators of a possible groundwater flow path from a saturated pit (HSI, 2003).

The potential impacts to these springs would likely include increased acidity with eventual increased concentrations of dissolved metals, such as aluminum, cadmium, copper, iron, manganese, nickel, zinc, and other constituents, such as sulfate and total dissolved solids. The flows and quality of springs having hydrologic connections to the pit did not noticeably decrease during operations, even with the drought (HSI, 2003). These flows could increase and their water quality decrease somewhat from levels experienced during mining due to the recovery of groundwater levels and hydraulic head in the pit under this alternative. This alternative is more likely to increase discharges of ARD at existing springs around the pit area, or create new springs or seeps impacted by ARD from the pit, than alternatives that maintain the pit as a hydrologic sink.

There is a reasonable likelihood that, under the Partial Pit Backfill With Downgradient Collection Alternative, one or more existing springs could be adversely impacted by the discharge from a backfilled pit. These potential water quality impacts could trigger an MPDES permitting review by DEQ. There is an additional potential for the creation of new springs or seeps around the backfilled pit in locations where the hydraulic head in the pit is greater relative to the groundwater elevations in possible groundwater pathways from fractures and old mine workings (HSI, 2003). Such new springs would also be subject to an MPDES permitting review by DEQ.

Measure W-1, Stipulation 010-4 in the 1998 ROD, would be modified to monitor for increased discharges from existing springs and seeps and for new springs and seeps. Any change to springs and seeps quantity and/or quality, and their associated source of contaminants, would be subject to an MPDES permitting review by DEQ. For bonding purposes, the agencies have assumed that one existing spring, Stepan Spring, would have a 15 percent increase in flow that would have to be collected and treated, and that one new spring discharging 1.5 gpm would develop and would be collected and treated under an MPDES permit. The assumed flow rate changes are based on existing spring information for the area and are strictly assumptions for analysis purposes.

4.3.4.2.2 Risk of Violation of Surface Water Standards and Beneficial Uses of the Jefferson River and Slough

4.3.4.2.2.1 Impacts from Waste Rock Dump Seepage

Impacts from 1 to 3 gpm of seepage from the East Waste Rock Dump Complex in Rattlesnake Gulch under this alternative would be the same as under the Partial Pit Backfill With In-Pit Collection Alternative.

4.3.4.2.2.2 Impacts from Pit Seepage

Pit seepage under this alternative would be more likely to reach the Jefferson River alluvial aquifer and the Jefferson River and Slough. Pit seepage would be allowed to leave the pit and reach the Tdf/colluvial aquifer, where it would be partially captured by two lines of capture wells and other wells on flow paths (Table 4-8). Two groundwater capture systems, a new one in Rattlesnake Gulch (see Figure 4-5) and the Tailings Impoundment No. 1 south pumpback system, would be used to try to capture this seepage. The point of control of the pit seepage would be much closer to the Jefferson River alluvial aquifer. There is little attenuation capacity in the Tdf/colluvial aquifer. High capture efficiencies are not reliably assured, as described in Section 4.2.3.1.2. At 92% combined capture efficiency, the DEQ-7 surface water standard for aluminum would be exceeded in the Jefferson Slough (HSI, 2006, 2007). In addition, as described in Chapter 6, Response to Comment #58, nondegradation criteria for the Slough fail

for aluminum, copper and iron. Control of potential pit seepage along secondary pathways is another complication. The risk of contaminants reaching the Jefferson River Slough or Jefferson River is greater than for alternatives that maintain the pit as a hydrologic sink.

4.3.4.3 Reclamation Plan Changes

4.3.4.3.1 Surface Disturbance

Surface disturbance for the Partial Pit Backfill With Downgradient Collection Alternative would be similar to the Partial Pit Backfill With In-Pit Collection Alternative, except 2 additional acres would be disturbed for downgradient collection wells, access roads, pipelines, and powerlines (Table 4-6). The number of acres on 2H:1V slopes requiring coversoil rock amendments under this alternative would be the same as the Partial Pit Backfill With In-Pit Collection Alternative.

4.3.4.3.2 Hazards to Wildlife

Hazards to wildlife under this alternative would be similar to the Partial Pit Backfill With In-Pit Collection Alternative, except that there is a greater potential for impacts to springs down gradient of the pit.

4.3.4.3.3 Total Remaining Unrevegetated Acres

There would be no remaining unrevegetated pit acres under this alternative.

4.3.5 Underground Sump Alternative

Under this alternative, the underground workings beneath the pit would be adapted to be used as a sump for removing water from the pit and routing it to the water treatment plant after closure. The design of the underground collection system is discussed in Section 2.4.5.3. The pit would be maintained as a hydrologic sink, similar to the No Pit Pond Alternative and Partial Pit Backfill With In-Pit Collection Alternative. The ultimate pit design would be the same as the other alternatives, except no material would be backfilled into the bottom of the pit. A new portal would be developed at the 4,550-foot elevation to replace the 4,857-foot portal, which was eliminated during Stage 5B mining. Only rock raveling off the highwall over time and highwall rock from assumed failures would accumulate on the pit bottom, as described in Section 4.2.4.9.1.

Compared to other alternatives, groundwater and precipitation entering the pit would encounter the least amount of acidic rock in the lower pit, which is estimated by the agencies to be 200,000 cubic yards (300,000 tons) over the long term, prior to being captured and sent to treatment. Unlike the No Pit Pond Alternative, a staging area for pumping facilities would not be required inside the pit. Underground access would, however, still need to be maintained. As a contingency against failures, which could destroy the 4,550-foot-elevation portal, the agencies would require GSM to submit a plan for development, maintenance and monitoring of a portal at a suitable alternative elevation. If the 4,550-foot-elevation portal is inaccessible, GSM would have to submit a plan for a secondary escape way and access to the underground workings. Additional details on the design of this alternative may be found in Section 2.4.5.

4.3.5.1 Impacts to Groundwater Quality and Quantity

4.3.5.1.1 Risk of Impacts to Groundwater Quality and Quantity in Permit Area

4.3.5.1.1.1 Impacts from Waste Rock Dump Seepage

Impacts to groundwater resources associated with the East Waste Rock Dump Complex seepage are generally the same as were described for the No Pit Pond Alternative.

This alternative would result in the largest amount of waste rock in the final East Waste Rock Dump Complex. Based on the relative mass of waste rock, the difference between this alternative and the No Pit Pond Alternative is only about 0.1 percent.

4.3.5.1.1.1.1 Long-Term Monitoring and Mitigation for Unanticipated East Waste Rock Dump Complex Seepage

Long-term monitoring and mitigation under this alternative would be the same as the No Pit Pond Alternative and all other alternatives.

4.3.5.1.1.1.2 Summary of East Waste Rock Dump Complex Seepage Impacts to Water Quality and Water Quantity

Impacts to groundwater under this alternative would be essentially the same as the No Pit Pond Alternative and all other alternatives.

4.3.5.1.1.2 Impacts from Pit Seepage

4.3.5.1.1.2.1 Impacts to Water Quality

Water-related impacts from the pit under this alternative would be similar to those for the No Pit Pond Alternative. Since no waste rock would be placed in the pit, groundwater and precipitation entering the pit would have contact ultimately with 200,000 cubic yards (300,000 tons) of acid-producing rock.

Water quality in the pit under the Underground Sump Alternative would be similar to the No Pit Pond Alternative. Under the Underground Sump Alternative, pumping regularly would remove pit water from the underground sump and send it to the water treatment plant. The regular pumping would minimize changes in groundwater quality and maintain the pit as a sink, with a cone of depression in the potentiometric surface centered on the pit similar to that which presently exists, but 25 to 75 feet deeper. No ARD impacts to groundwater quality outside the pit would be anticipated. If ARD pumped from the pit exceeds the expected rates, mitigation Measure W-6 approved in the 1998 ROD as Stipulation 010-9 would provide for additional water treatment plant capacity to treat the additional flows.

4.3.5.1.1.2.2 Impacts to Water Quantity

A pit water balance model was developed in the 1997 Draft EIS, Table IV-5, which accounted for total inflows and outflows (Hydrometrics, 1995). That model found that complete dewatering of the pit to the 4,700-foot pit floor permitted at that time would require removal of approximately 102 gpm.

The revised SEIS water balance model is described under the No Pit Pond Alternative, Section 4.3.2.1. This SEIS model was calibrated to recent pumping records to predict pit dewatering under the Underground Sump Alternative. Average inflow under the Underground Sump Alternative is expected to be the same as that of the No Pit Pond Alternative. Although the pumping level in the

underground sump would be 25 to 75 feet deeper than in the No Pit Pond Alternative, the rate of groundwater inflow from the underground workings would be minimal (H. Bogert, GSM, personal communication, 2004).

This SEIS has generally found that the water-related impacts of this alternative would be similar to those predicted in the 1997 Draft EIS, Chapter IV, Section IV.B.6 for the No Pit Pond Alternative, except that the long-term pumping rate from the pit sump is projected to be from 25 to 27 gpm, instead of the 102 gpm predicted in the 1997 Draft EIS.

Potential water resource impacts from the Underground Sump Alternative would be limited to possible additional reductions in the bedrock groundwater level and the flows of springs hydrologically connected to the pit, as a result of the continued pit dewatering. This is an unavoidable impact of maintaining the pit as a hydrologic sink.

4.3.5.1.1.2.3 Summary of Pit Impacts to Water Quality and Quantity

Under this alternative, 25 to 27 gpm would be pumped out of the underground sump and treated. Water quality would be similar to that predicted in Table 4-5. Pumping from the underground workings would provide complete control of the predicted pit water discharge. It would be relatively easy to pump from the underground sump as long as access is maintained. The agencies would require a contingency portal location for secondary access to ensure continued pumping and worker safety. As long as access to the underground is maintained, it is relatively easy to repair, replace, and maintain the dewatering system under this alternative. If the predicted pit flows were twice as much as predicted, the dewatering system could easily be upgraded and routed to the water treatment plant. GSM proposed to test in-situ treatment of the water in the underground sump during the 2004-2005 mill shutdown (GSM, 2004). The testing program was never fully implemented due to accessing the pit bottom during mining operations. The wells were installed, lime was placed in the underground, and some chemicals were initially added. Testing was not completed nor is it planned as the pit dewatering has lowered the water below the pumps in the test wells (Shannon Dunlap, personal communication, 2007). Pretreatment of the water in the sump may be possible and has been done at GSM (Shannon Dunlap, GSM, personal communication, 2006). It is anticipated that pit water quality would be slightly better under the Underground Sump Alternative than under the partial pit backfill alternatives because of less contact with reactive rock.

4.3.5.1.2 Risk of Violation of Groundwater Standards at Permit Boundary and Impacts to Beneficial Uses of the Jefferson River Alluvial Aquifer

4.3.5.1.2.1 Impacts from Waste Rock Dump Seepage

The impacts from waste rock dump seepage would be the same as under all the other alternatives.

4.3.5.1.2.2 Impacts from Pit Seepage

The pit would be maintained as a hydrologic sink under this alternative with no additional risk to the Jefferson River alluvial aquifer. If ARD from the pit exceeds the expected rates, provisions such as mitigation Measure W-6 approved in the 1998 ROD as Stipulation 010-9 would provide for additional permanent water treatment plant capacity to treat the additional flows. No untreated water would migrate toward the Jefferson River alluvial aquifer. Water treatment plant effluent would be discharged below Tailings Impoundment No. 2 and would migrate to the Jefferson River alluvial aquifer.

The principal consequence of failure of this alternative would be the creation of an ARD-impacted pit pond. In the Pit Pond Alternative, which was dismissed in Section 2.5.4, the water level in the pit would have risen to the 4,635-foot elevation. Under the Underground Sump Alternative, no backfill would be placed in the pit and 200,000 cubic yards (300,000 tons) of highwall rock would ravel and slough over time. The additional 200,000 cubic yards of material would raise the pit lake a maximum of 32 feet, to approximately the 4,667-foot elevation. This is below the 5,050-foot elevation at which water would begin to seep out of the pit. Since control of water from a pit pond can be accomplished by direct pumping and treating, no adverse impacts to groundwater outside the pit would be anticipated. In addition, water in a pit pond could be more easily pretreated before pumping to the water treatment plant.

4.3.5.2 Impacts to Surface Water Quality and Quantity

4.3.5.2.1 Impacts to Springs, Wetlands

4.3.5.2.1.1 Impacts from Waste Rock Dump Seepage

The impacts to springs and wetlands from waste rock dump seepage would be the same as the No Pit Pond Alternative.

4.3.5.2.1.2 Impacts from Pit Seepage

Under the Underground Sump Alternative, pit water elevations would be maintained within the underground sump, with the pumping level ranging from

4,450 to 4,500-foot elevation. This would be 25 to 75 feet deeper than the water level that would be maintained under the No Pit Pond and Partial Pit Backfill With In-Pit Collection alternatives. Long-term impacts to springs would be similar to those that are predicted under the No Pit Pond Alternative, Section 4.3.2.2.1.2, except that the water table may be further reduced by the 25 to 75-foot deeper cone of depression.

If the groundwater system has not reached equilibrium at the conclusion of mining Stage 5B, long-term impacts to springs from pit dewatering may be somewhat greater than impacts during mining operations and predictions from the 1997 Draft EIS and this SEIS. GSM maintains a spring monitoring program, including flow rates and water quality (GSM, 2002a). Continued monitoring and mitigation measures similar to mitigation Measure W-1 approved in the 1998 ROD as Stipulation 010-4, which requires spring flow and water quality monitoring, would be required.

4.3.5.2.2 Risk of Violation of Surface Water Standards and Impacts to Beneficial Uses of the Jefferson River and Slough

4.3.5.2.2.1 Impacts from Waste Rock Dump Seepage

Impacts from waste rock dump seepage on surface water quality and quantity would be the same as under the No Pit Pond Alternative.

4.3.5.2.2.2 Impacts from Pit Seepage

Impacts from pit seepage under this alternative would be the same as the No Pit Pond Alternative, which predicted no impacts to the Jefferson River and Slough in the 1997 Draft EIS and this SEIS.

4.3.5.3 Reclamation Plan Changes

4.3.5.3.1 Surface Disturbance

Surface disturbance for the Underground Sump Alternative would be similar to the No Pit Pond Alternative. About 285,600 cubic yards of stockpiled soil would be used to revegetate the 52 acres to be reclaimed (7 acres already reclaimed) of pit disturbance.

4.3.5.3.2 Hazards to Wildlife

Hazards to wildlife under this alternative would be the same as the No Pit Pond Alternative.

4.3.5.3.3 Total Remaining Unrevegetated Acres

About 159 acres of the pit disturbance area would be left unrevegetated.

4.4 SOCIOECONOMIC ISSUES

4.4.1 Introduction

Analyses for this SEIS are based on the assumption that GSM would complete Stage 5B, which should extend operations through 2008 (GSM, 2002a). Selection of a pit closure alternative might directly affect the economics on which future mining decisions are based. Moreover, after this mine has been shut down, the type of pit closure that is implemented could have a continued impact on the prospects for future development of the potential remaining mineral resource.

The proposed action in the 1998 Final EIS provided for mining operations to continue through 2006. No increase in work force was expected. Because GSM was in operation and no new work force was required, no changes were expected with regard to population, housing, schools, water supply, waste water treatment, solid waste disposal, fire protection, law enforcement, health care, or community recreation. Tax revenue and other economic benefits would be discontinued at the end of the mine life at the end of 2006.

This SEIS took a more detailed look at the socioeconomic issues. This included evaluating issues such as cultural resources, noise, safety, aesthetics, employment opportunities, revenue from taxes, mineral resources/reserves, and future burden on society and the company (Robertson GeoConsultants, 2003).

Initiation of mining the Stage 5B pit in October 2003 increased mine employment. Underground mining added contractor personnel to the total work force.

4.4.2 No Pit Pond Alternative (No Action)

4.4.2.1 Safety

The topography of the mine area would differ depending on the reclamation alternative that is implemented and would affect safety. The No Pit Pond Alternative has limited backfill, and the pit would be maintained in about the same configuration left by mining. The highwall would have cliff-like configurations that would be hazardous. Stability of the highwall could degrade over time producing periodic raveling and sloughing as described in Section 4.2.1.2.2.

4.4.2.1.1 Risk to Workers (Reclamation and Construction)

After Stage 5B is completed, reclamation and construction of the dewatering system would begin. In the 1997 Draft EIS, Chapter IV, Section IV.N.6 under the

No Pit Pond Alternative, in order to provide safe access to the floor of the pit for construction and operation of the dewatering system, the pit would have been partially backfilled with waste rock from the 4,700-foot to the 4,800-foot elevation, creating a flat working surface of 7.4 acres. In this SEIS under the No Pit Pond Alternative, in order to provide safe access to the floor of the pit for construction and operation of the dewatering system, the pit would be partially backfilled with crusher reject from the 4,525-foot to the 4,625-foot elevation (GSM, 2002a).

This partial backfilling of the pit would allow creation of a flat working area of approximately 1.3 acres (300 feet by 225 feet). Although the area is smaller than the area in the 1997 Draft EIS, the pit highwall at this elevation is more stable than envisioned in 1997 due to the pre-split blasting techniques employed. In addition, there would remain a 70-foot-wide safety bench at the 5,700-foot elevation above three sides of the working area for additional protection. Additional protection would be provided by building one or more berms around the perimeter of the working area to trap incidental rocks that may fall from the highwall. The agencies would require the road leading down to the working area from the 4,875-foot elevation to be widened where possible, depending on the final pit configuration, by extending the road to the south over a portion of the 4,800-foot-elevation area and away from the highwall toe.

Under the No Pit Pond Alternative, trucks loaded with crusher reject would have to drive down the 8 to 12-percent-grade pit haul road to deposit the backfill in the bottom of the pit. Hauling 111,000 cubic yards (167,000 tons) of crusher reject down the pit haul road would expose drivers to an increased hazard for up to 3 months. Because of this risk, GSM's safety policy would require trucks to be operated partially loaded.

Operating bulldozers to level the backfill and drilling equipment to install the dewatering wells below the pit highwall would expose workers to some risk. Although pit safety benches would be maintained to minimize hazards to workers, operating equipment below unstable areas would be a concern.

The safety risk to reclamation workers under the No Pit Pond Alternative is increased while backfill is being hauled down the steep roads into the pit, because the potential for truck accidents would be increased mainly from brake failures. In addition, the workers would be below a highwall of up to 1,875 feet increasing the risk of injury from rock falls.

The Mine Safety and Health Administration (MSHA) tracks mine related injuries and reports national average non-fatal, days lost (NFDL) accident rates. These numbers for surface metal mines have ranged from 1.79 to 2.82 NFDLs per year from 1993 through 2006 (www.msha.gov). No attempt was made to assign lost time accidents by alternative. The longer reclamation takes, the higher the likelihood of having NFDLs or even a death. Under the No Pit Pond Alternative,

reclamation would take 23 person years to complete, and total mine reclamation and construction would take about 123 person years to complete.

4.4.2.1.2 Risk to Workers (Long-Term Maintenance)

Under the No Pit Pond Alternative, workers in the pit would be exposed to pit highwall raveling and sloughing hazards from the 1,775-foot highwall. The No Pit Pond Alternative would require long-term access to the pit bottom for monitoring and maintenance of the pit haul road, 5,700-foot-elevation pit safety bench, and the dewatering system.

4.4.2.1.3 Risk to Public Safety

Access restrictions on general public use would be maintained under the No Pit Pond Alternative. Access restrictions would consist of signs, berms, and fencing around the pit area, but there would still be a risk to public safety because of the pit highwall.

4.4.2.2 Mining Employment

4.4.2.2.1 Potential Employment from Mining Stage 5B

The 1997 Draft EIS, Chapter IV, Section J.2.a predicted employment and potential tax revenues for mining the Stage 5 pit. Table 4-10 summarizes employment opportunities and potential tax revenues of the alternatives in this SEIS through the end of Stage 5B compared with the projections from the 1997 Draft EIS.

Table 4 - 10. Total Mining Employment and Economic Benefits of GSM Through Stage 5B

ITEM	1997 Draft EIS Projection (1997-2011)	SEIS Projection (1997-2009)	Current (1997-2005)
Average Number of Employees (1997 thru 2011)	96 (average)	119	138
Salaries	60,111,200	82,918,724	69,124,605
Payroll Taxes	4,872,000	16,583,745	6,680,835
Benefits	11,038,850	33,167,490	16,427,905
Revenue from Taxes Paid (Property, Gross Proceeds, Metals Mine License, State)	21,523,400	19,125,719	13,770,841
Purchases of Goods and Services, Inside and Outside of Montana	386,516,279	367,117,592	252,178,212
Total	484,061,729	518,913,270	358,182,398

Under the No Pit Pond Alternative, GSM would be expected to complete mining and reclamation tasks within a period of 10 years. The continued operation of the mine under Stage 5B would provide employment for mine personnel. No new work force would be expected from current levels. No new changes induced by the project are anticipated with respect to population, housing, schools, water supply, wastewater treatment, solid waste disposal, fire protection, law enforcement, health care, or community recreation.

Since 1983 when major mining development was initiated at GSM, employment has ranged from 74 to 301 employees. As of May 2006, GSM employed a total of 157 persons with an additional 22 contractor personnel. GSM has maintained a policy of hiring from the local area when possible since inception of operations. The number of employees needed to complete Stage 5B mining would vary by year. There is also a multiplier effect for secondary employment opportunities. This effect results in other indirect employment opportunities.

Upon completion of Stage 5B mining and mine closure under all alternatives, there would be an immediate staff reduction. When employment terminates, workers would find other jobs locally or relocate, depending on job availability. Workers remaining in the area would continue to make demands on community services and could increase the demand on assistance programs.

The community of Whitehall would experience impacts from closure of the mine. Typically, approximately 65 percent of the GSM workforce resides in the

Whitehall area. It is estimated that as of June 2004, 10 percent of the town's population is employed full time at the mine (104 people out of a population of 1,044). If a typical family of three is assumed, approximately 30 percent of the population would be estimated to be dependent on GSM employment. In addition, mining jobs support secondary employment in the services sector and other industries (Table 4-10).

The anticipated mining employment opportunities from mining Stage 5B under the No Pit Pond Alternative are 750 person years.

4.4.2.3 Reclamation Employment

4.4.2.3.1 Reclamation Employment Opportunities

After mining ceases, a reduced labor force would be employed for a period of up to 3 years to complete reclamation and to prepare the site for long-term water treatment. About 2 years would be required to decommission the facilities, place 100 feet of crusher reject in the pit bottom, and reclaim other disturbed areas. The predicted employment opportunities during reclamation under the No Pit Pond Alternative are 123 person years. Only about 23 person years of this total would be attributable to pit closure tasks. Following pit closure, dewatering and water treatment would continue indefinitely, requiring a full time staff of less than ten. Reclamation would end about 2010. After reclamation is complete, continued employment would occur at a reduced level to maintain the site, provide monitoring, and operate the dewatering and water treatment systems. Under the No Pit Pond Alternative, about two to five employees would be needed indefinitely.

4.4.2.4 Revenue from Taxes

4.4.2.4.1 Potential Tax Revenues from Mining Stage 5B

Estimates of tax revenue were made for the completion of mining of Stage 5B, which included property tax, metalliferous mines license tax, gross proceeds tax, and state payroll tax. No federal taxes were included. Payroll tax was estimated on averages for employee salaries for the number of person years estimated for the mining employment section above. The estimated tax revenue from Stage 5B mining under the No Pit Pond Alternative would be $8,087,000.

In 2002, GSM paid $821,866 in metal mine license tax, $492,362 in gross proceeds tax, and $309,232 in other property taxes. The total tax payment was $1,623,460.

In 2003, GSM paid $1,217,076 in metal mine license tax, $412,675 in gross proceeds tax, and $215,115 in other property taxes. The total tax payment was $1,844,866. Comparable tax payments would be expected during the years that

Stage 5B is mined, except during the waste rock stripping when no gold was produced.

The socioeconomic impacts from closure and reclamation would be the loss of tax payments. Taxes based on production would end with the completion of mineral processing. Property taxes would gradually decrease with the decommissioning of facilities, but would be maintained indefinitely at some level on the land and the dewatering and water treatment system.

4.4.2.4.2 Potential Tax Revenues from Pit Backfill

After Stage 5B mining is completed, the only taxes paid by GSM during reclamation would be property taxes. Estimates of potential tax revenue for reclamation activities include property tax and state payroll tax. No federal taxes were included. The estimated tax revenue from reclamation under the No Pit Pond Alternative would be $319,500.

4.4.2.5 Mineral Reserves and Resources

4.4.2.5.1 Access to Future Mineral Reserves/Resources

Precious metal mineralization extends beyond the planned limits of the open pit floor and highwall for Stage 5B (GSM, 2002a). There might be additional resources that have not been identified by exploration activities. The minerals may not be considered feasible to mine under current economic conditions and technology. Changes in external conditions, such as fluctuating metals prices and improvements in technology, may result in revised open pit designs, which could increase the amount of economically extractable ore some time in the future. If these resources are buried due to backfilling requirements, the cost of recovering them in the future may be so high that the resource would be unavailable. Although it is technically possible to remove the backfill material, it may not be economically feasible to remove the remaining gold.

A mineral resource is defined as a concentration or occurrence of natural, solid, and inorganic material in or on the earth's crust in such form and quantity and of such grade or quality that it has reasonable prospects for economic extraction. The definitions utilized by Barrick for reporting conform to Canadian Institute of Mining, Metallurgy and Petroleum definition of these terms as of the effective date of estimation, as required by National Instrument 43-101 of the Canadian Securities Administrators.

One of the purposes of MMRA is to prevent foreclosure of future access to mineral resources not fully developed by current mining operations (82-4-302(1)(f), MCA). However, MMRA does not direct DEQ to adopt pit reclamation alternatives that would allow future access to unmined reserves. The degree of future accessibility of the remaining gold-bearing mineralization would in part

determine the future mining potential for the remainder of the resource. That accessibility would be influenced by the pit reclamation plan chosen.

Three factors of the pit reclamation plan that could affect future mining potential include:

- Amount of backfill placed in the pit;
- Amount of highwall rock that would ravel and slough into the pit over time; and
- Ability to dewater the saturated portion of the backfill.

Under the No Pit Pond Alternative, the pit would be backfilled from 4,525 to 4,625 feet. About 111,000 cubic yards (167,000 tons) of backfill and 290,400 cubic yards of soil would have to be removed from 60 acres if the pit were enlarged for additional mining in the future. In addition, as described in Section 4.2.1.2.2, the agencies expect some highwall rock to ravel and slough into the pit over time, some of which would have to be removed.

The agencies have assumed 100,000 cubic yards (150,000 tons) of highwall rock would ravel over time. In addition, another 100,000 cubic yards would slough into the pit as a mass failure of the highwall, which would bury the dewatering system. The 5,700-foot safety bench would have to be reestablished for access and safety. This would produce an unknown volume of highwall rock. More backfill would have to be hauled into the pit to create a new flat working surface and reestablish the dewatering system wells. As a result, soil cover and 200 feet of highwall rock and backfill or a minimum of 600,000 cubic yards (900,000 tons) would have to be removed before mining could begin again.

The pit would have to be dewatered before enlarging the pit in the future. The dewatering system needed to dry out the saturated backfill would already be in place, but may be destroyed as the mine is expanded. Because only the bottom 200 feet of the pit would be filled with waste rock, the time required to dewater the pit for continued mining would be less than the partial pit backfill alternatives. During 2002 mining, an average of 405,333 cubic yards (608,000 tons) of waste rock and ore was removed from the bottom of the pit per month. Assuming a similar mining rate, it would take 1.5 months to remove 600,000 cubic yards.

Because of the limited amount of rock that would have to be removed, the waste-to-ore ratio would not increase substantially. In addition, the time required to dewater the pit would be minimal. This alternative would have a limited impact on future recovery of mineral resources. Under this alternative, the potential would remain for continued exploration and possible future mining with minimal implementation problems.

4.4.2.6 Land Use After Mining

4.4.2.6.1 Suitability of Land Use after Mining

Land uses of the permit area before mining consisted of wildlife habitat, livestock grazing, agriculture, timber, recreation, and industrial use, as discussed in Section 3.8. Within the area of the open pit, the steep terrain limited activities such as livestock grazing and precluded other agriculture land uses. So, prior to construction of the open pit mine, this area was used for wildlife habitat, limited livestock grazing, and mining. Because timber is sparse in this area, timber harvesting has not been impacted. The only recreation activities that likely could have occurred in the area in the past were hunting and hiking, which were dependent on the permission of the previous owner.

Land use after mining was judged in terms of the suitability of the alternative to achieve that land use. In all cases, that land use would be a reclaimed mine with monitoring, maintenance, water treatment, and wildlife habitat. Under the No Pit Pond Alternative, 60 acres in the pit would be revegetated as mule deer habitat, and 158 acres would be reclaimed as steep cliffs. GSM would also develop a small portion of the highwall in the pit to provide bat and raptor habitat on the upper oxidized highwall, as described and evaluated in the 1997 Draft EIS, Chapter IV, Section IV.E and described in this SEIS in Section 2.4.2.6. Observations at other mines suggest that the following species could use the GSM highwall at the conclusion of mining: golden eagle, red-tailed hawk, great horned owl, common raven, rock wren, fringed myotis, long-legged myotis, Yuma myotis, long-eared myotis, and western small-footed myotis, all BLM sensitive species (SRK, 2005). Mines at which these observations were made include several non-ARD pits (REN, Dee Gold, Sunshine, Marigold, Bald Mountain, and Robertson) and several having ARD potential (Gold Quarry, Reona, Gold Hole, and Coeur Rochester) (G. Back, SRK, personal communication, 2005). No conclusions were made on whether any nests were in sulfide material.

Under the No Pit Pond Alternative, additional disturbance of lands would not occur. The pit area would be maintained as a hydrologic sink with the pit bottom being used to capture and collect contaminated water. A fence, signs, and berms would be constructed around the open pit to discourage large mammals including humans from entering the area. The industrial usage at the bottom of the pit and the fence would not preclude bats and raptors from using the upper oxidized pit highwall and mule deer from using the revegetated areas within the pit.

Approximately 5 acres of existing disturbance would be used for the dewatering system and access roads in the pit. Hunting and other recreational activities around the pit and in other operational areas would be prohibited. The primary land use impact under this alternative would be the permanent loss of 158 acres of mule deer habitat.

4.4.2.7 Aesthetics

Visual resources impacts were evaluated in the 1997 Draft EIS, Chapter IV, Section IV.I.

4.4.2.7.1 Visual Contrast With Adjacent Lands

The impact the No Pit Pond Alternative would have on visual resources was evaluated in the 1997 Draft EIS, Section IV.I. It was determined that, for the pit under this alternative, visual contrasts would be reduced to a level where they would be noticeable but not dominant in the landscape, following successful reclamation and revegetation. Landscape modifications for the area would be consistent with a Class III rating according to the BLM's visual resource management system.

A high degree of visual contrast would relate to a poor aesthetic value. As stated in the MMRA with regard to open pits and rock faces, the reclamation plan must provide sufficient measures for reclamation to a condition that mitigates visual contrasts between reclamation lands and adjacent lands.

Since the 1997 Draft EIS evaluation, the design of the pit highwall and the scope of the proposed reclamation plans have changed with respect to this issue. The one notable change in the pit design is the elevation at which the haul road enters the pit at the low point on the pit rim. The plan was to cut a 32-acre notch out of this section of the pit highwall and lower the road by 150 feet. The existing configuration eliminates the need for the notch and hides more of the pit from view from all vantage points below the pit rim.

Recontouring and revegetating portions of the pit would reduce the visual contrast with adjacent undisturbed lands. GSM has proposed to revegetate 60 acres in the 218-acre pit, of which 15 acres would be visible. The measures that would be used to reduce visual contrast under the No Pit Pond Alternative include planting trees around the pit perimeter where possible, and, where safety allows, seeding and planting trees on final oxidized benches containing enough fine material to support plant life (GSM, 2002). The raveling and sloughing of pit highwalls over time would reduce visual contrast.

To further reduce visual contrast, the agencies would require GSM to seed and plant trees on additional safely accessible areas in the pit above the 5,700-foot safety bench (see Section 4.8.3.2). The agencies would also require GSM to extend the East Waste Rock Dump Complex across the mouth of the pit to tie into the natural slope and partially screen the view of the highwall (see Section 4.8.3.2).

4.4.2.8 Potential Future Burden

4.4.2.8.1 Potential Future Burden on Society

Operation and maintenance of reclaimed mines involves infrastructure used to collect, treat and release the impacted water, divert clean water, and maintain covers, etc. Over time, some facilities would need to be upgraded, rebuilt or replaced. Monitoring programs would be required. While all activities after mining would be the responsibility of GSM and would be bonded, site management may become the responsibility of another private or agency custodian. The long-term nature of these requirements at GSM suggests a risk to society to inherit the burden if the responsible party fails in its obligations.

The complexity of the dewatering and water collection systems and the uncertainty of collecting all pit water would be the largest potential burden on society under any alternative. Under the No Pit Pond Alternative, these systems for the pit area would consist of two to three 100-foot-deep wells, a powerline, and a pipeline to the water treatment plant. Pit highwall failures expected over time would increase the depth of the wells needed to 200 feet.

The principal consequence of failure of long-term implementation of the No Pit Pond Alternative would be creation of an ARD-impacted pit pond below the 5,050-foot elevation, as described in Section 4.2.1.9.2. Below this elevation, less than 10 percent of the water would not flow out of the pit. No impacts to groundwater outside the pit would be anticipated. The risk of this alternative to create a future burden on society is low because water resource impacts to seeps and springs would be minimal. Beneficial uses of the Jefferson River alluvial aquifer would not be impacted, as described in Section 4.3.2.1.2.2.

In addition, future treatment technologies could easily be implemented. Pit water would be completely controlled.

4.4.2.8.2 Potential for Future Liabilities for GSM

The complexity of the alternative pit reclamation plan could affect GSM's ability to comply with the operating permit requirements and water quality standards. Liabilities from the alternatives would be based on the potential for water quality degradation related to the amount of backfill, complexity of the dewatering system, and continued access to the dewatering system for operation and maintenance.

Under the No Pit Pond Alternative in both the 1997 Draft EIS and this SEIS, there would be no water quality degradation outside of the pit. The water level, even with backfill and pit highwall rock that has raveled and sloughed to the pit bottom over time, would not reach the 5,050-foot elevation. Therefore, no untreated water would leave the pit. In addition, if the dewatering system failed for any

reason, it could be re-established on the regraded pit bottom through the expected 200 feet of backfill and highwall rock more easily than under an alternative with up to 875 feet of backfill. Continued safe access to the dewatering system for operation and maintenance under the No Pit Pond Alternative would be more difficult than the partial pit backfill alternatives because of highwall rock raveling and sloughing onto access roads and the changing condition of the roads. Removing water from the backfill would be easier because of the agency-assumed 600,000-cubic-yard volume of material from which the water would be pumped and the depth of the wells in the 200 feet of rock in the pit bottom. GSM contends it could comply with groundwater quality standards under the No Pit Pond Alternative (GSM, personal communications, 2003).

4.4.3 Partial Pit Backfill With In-Pit Collection Alternative (Proposed Action)

4.4.3.1 Safety

4.4.3.1.1 Risk to Workers (Reclamation and Construction)

The Partial Pit Backfill With In-Pit Collection Alternative would backfill the pit to a free-draining elevation of 5,350 feet and would reduce all of the pit highwall above this elevation to 2H:1V slopes. All of the 254 pit acres would be covered with 3 feet of soil and revegetated (Table 4-6).

Risk to workers could arise from a number of activities.

- Hauling 111,000 cubic yards (167,000 tons) of crusher reject to the bottom of the pit for the sump under the Partial Pit Backfill With In-Pit Collection Alternative would be the same as for the No Pit Pond Alternative.
- Hauling and end dumping 33,200,000 cubic yards (50,000,000 tons) of waste rock from the edge of the pit that is hundreds of feet deep would expose drivers to limited hazards for 50 to 80 months. This activity is similar to end dumping used to create the waste rock dump complexes.
- Drilling and cast blasting 11,900,000 cubic yards (17,900,000 tons) of pit highwall and dozing blasted materials down to create 2H:1V slopes would expose workers to fall and rollover hazards for about 30 to 36 months.
- Constructing roads on steep slopes and hauling soil along narrow benches and spreading soil on long 2H:1V slopes would expose workers to hazards for 10 to 12 months.

The safety risk to reclamation workers would be the same as under the No Pit Pond Alternative while 100 feet of crusher reject is being hauled down the steep roads into the pit because of the potential for truck accidents, especially from brake failures. After placement of the sump material to the 4,625-foot elevation, pit backfilling to the average elevation of 5,400 feet would be accomplished by end dumping waste rock from the pit rim. This is the standard method used during mining to create waste rock dumps and has less risk than hauling loaded trucks to the bottom of the pit.

Cast blasting and dozing would be used to reduce the pit highwall to a 2H:1V slope above the 5,400-foot elevation. Operating bulldozers to create the final slopes would have risk similar to that of reducing the slopes of waste rock dumps. All of the highwall would be eliminated. Workers installing, operating,

and maintaining the dewatering system would not be working in a pit below a 1,775-foot highwall and would not be at risk of injury from rock falls.

Pit reclamation would take 108 person years. Total reclamation and construction would take about 308 person years to complete.

4.4.3.1.2 Risk to Workers (Long-Term Maintenance)

Under the Partial Pit Backfill With In-Pit Collection Alternative, long-term access to the pit bottom would not be required. Worker safety over the long term relates primarily to monitoring and maintenance of the reclaimed pit slopes and benches and the dewatering system. The risk to worker safety in this alternative would be less than the No Pit Pond Alternative and would be similar to work conducted on the reclaimed portions of the waste rock dump complexes.

4.4.3.1.3 Risk to Public Safety

Access restrictions on general public use would be maintained under the Partial Pit Backfill With In-Pit Collection Alternative. Access restrictions would consist of signs, berms, and fences, and there would be less risk to public safety because the pit highwall would be eliminated.

4.4.3.2 Mining Employment

4.4.3.2.1 Potential Employment from Mining Stage 5B

Impacts associated with mine operation under the Partial Pit Backfill With In-Pit Collection Alternative would be the continued economic benefits of employment and income provided by the mine and county and state tax revenues throughout the mine's projected life span to 2008. The anticipated mining employment opportunities from mining Stage 5B under the Partial Pit Backfill With In-Pit Collection Alternative would be 750 person years.

GSM has indicated that it may not be able to continue mining if a partial pit backfill alternative is selected (GSM, 2002a). Manpower requirements fluctuate on a routine basis during mining. Under this alternative, for each year lost by premature mine closure, mining employment would be reduced by approximately 150 person years, depending on the state of mining. There would be a loss of GSM's 139 full time and 42 contract jobs under this alternative (GSM, personal communication, September 2004).

4.4.3.3 Reclamation Employment

4.4.3.3.1 Reclamation Employment Opportunities

At the termination of mining, decommissioning of the facilities, partial backfilling of the pit, and reclamation of other disturbed areas would require an additional 3 years. The predicted employment opportunities during reclamation under the Partial Pit Backfill With In-Pit Collection Alternative would be 308 person years. About 108 person years of this total would be attributable to pit closure tasks. Following pit closure, dewatering and water treatment would continue indefinitely requiring a full time staff of approximately ten. Periodic requirements to repair settling and erosion damage, as well as repair and replace dewatering wells, would provide opportunities for other area service providers.

4.4.3.4 Revenue from Taxes

4.4.3.4.1 Potential Tax Revenues from Mining Stage 5B

The tax revenues from completing Stage 5B would be $8,087,000, the same as the No Pit Pond Alternative. GSM has indicated that mining may cease if partial pit backfilling is required. Under this alternative, for each year lost by premature mine closure, tax revenues would be reduced by $1,605,400. If GSM closes, property tax revenue would be $12,000 per year.

4.4.3.4.2 Potential Tax Revenues from Pit Backfill

Estimates of potential tax revenue for reclamation activities, primarily backfilling, include property tax and state payroll tax totaling $806,000 over a 3-year period. No federal taxes were included.

4.4.3.5 Mineral Reserves and Resources

4.4.3.5.1 Access to Future Mineral Reserves/Resources

Under the Partial Pit Backfill With In-Pit Collection Alternative, the pit would be backfilled from 4,525 feet to an average depth of 5,400 feet. A total of 111,000 cubic yards (167,000 tons) of crusher reject material, 33,200,000 cubic yards (50,000,000 tons) of backfill, 11,900,000 cubic yards (17,900,000 tons) of waste rock covering the highwall, and 1,541,800 cubic yards of soil would have to be removed from 274 acres if the pit was enlarged in the future.

The pit would have to be dewatered while removing the backfill and enlarging the pit in the future. The dewatering system needed to dry out the saturated sump material would already be in place, but would be destroyed while removing the backfill. The new dewatering system would have to be implemented in stages as part of the expanded mining operations as is done for regular mining operations

below the water table. It is expected the time required to dewater the pit would be longer than the No Pit Pond Alternative. Dewatering a pit backfilled with weathered waste rock could be as difficult as dewatering solid rock because of the amount of fine, cemented material in the weathered waste rock backfill. When the East Waste Rock Dump Complex was partially off-loaded after the 1994 ground movement, the waste rock had weathered into finer material. Ripping of the unsaturated waste rock was needed because of cementation and compaction (Herasymuik, 1996). GSM reported that some of the material required blasting. The agencies expect the same process would occur in the backfilled pit.

In order to re-open the pit after reclamation is completed under the Partial Pit Backfill With In-Pit Collection Alternative, a mining company would have to remove 47,000,000 cubic yards of backfill and soil, which includes the amount needed to re-establish the 5,700-foot pit safety bench and to gain access to mineralization below the former pit floor.

Because this amount of rock and soil would have to be removed, this alternative would increase the waste-to-ore strip ratio more than the No Pit Pond Alternative. This would affect the potential for future mining activity more than the No Pit Pond Alternative. Under this alternative, the potential for continued exploration and possible future mining could be limited. The backfill would not be as difficult to remove as solid rock. Assuming a mining rate similar to that used by GSM in 2002, removal of this volume of material could take about 10 years at 405,000 cubic yards per month. Part of the backfill material would be wet, including areas near preferential flow from seeps into the pit. During the years of backfill removal, more could saturate and removal could be more difficult.

4.4.3.6 Land Use After Mining

4.4.3.6.1 Suitability of Land Use After Mining

Under the Partial Pit Backfill With In-Pit Collection Alternative, nearly the entire pit area would be reclaimed to its primary pre-mining land use as wildlife habitat. This alternative would require the disturbance of an additional 56 acres of land on the steep hillsides around the perimeter of the pit from cast blasting and constructing haul roads to haul soil (Figure 2-4). The additional disturbance would be revegetated within a period of about 3 years. The intent of the reclamation plan for the pit disturbance area would be to establish a sustainable plant cover in all areas.

Approximately 1 to 2 acres would be required for the dewatering system and access roads in the reclaimed pit area and would have little utility as wildlife habitat. All other areas would be available for wildlife habitat. Due to the presence of maintenance personnel and equipment in the pit, hunting would be

prohibited in most areas. With removal of pit hazards, recreational activities outside the pit, such as hiking, and hunting could be permitted.

Under the Partial Pit Backfill With In-Pit Collection Alternative, 274 acres would be revegetated as mule deer habitat. GSM would not develop raptor and bat habitat on the upper highwall because there would be no highwall.

4.4.3.7 Aesthetics

4.4.3.7.1 Visual Contrast with Adjacent Lands

The 1997 Draft EIS, Chapter IV, Section IV.I evaluated the impact the Partial Backfill Alternative would have on aesthetics. It was determined that backfilling the pit to a daylight level and revegetating the upper pit slopes would partially restore the pit area and would decrease the contrasting forms, lines, and colors of the pit benches and highwall visible from key observation points. In addition, hauling waste rock material from the East Waste Rock Dump Complex to backfill the pit would reduce the height of some of the benches in the dump.

In this SEIS, the Partial Pit Backfill With In-Pit Collection Alternative would be similar to the Partial Backfill Alternative in the 1997 Draft EIS. The reclaimed 2H:1V slopes covering the pit highwall and the reclaimed slopes of the waste rock dump complexes would still be visible, but the overall contrasts would be reduced under this alternative.

4.4.3.8 Potential Future Burden

4.4.3.8.1 Potential Future Burden on Society

The complexity of the dewatering and water collection systems and the uncertainty of collecting all pit water would be the largest potential burden on society in the long term. Under the Partial Pit Backfill With In-Pit Collection Alternative, these systems would consist of up to 11 wells up to 875 feet deep, an access road, a powerline, and a pipeline to the water treatment plant.

Funding and infrastructure are required to collect and treat contaminated water after closure. The consequence of failure of this alternative due to technical or financial reasons is uncontrolled discharges of ARD-impacted groundwater from the backfilled pit, which could adversely impact springs (Section 4.3.4.2.1.2) and beneficial uses of the Jefferson River alluvial aquifer, as described in Section 4.3.4.1.2 for the Partial Pit Backfill With Downgradient Collection Alternative. Downgradient capture wells, as described in Section 4.2.3.5.1 for the Partial Pit Backfill With Downgradient Collection Alternative, would be needed as a contingency if the dewatering system failed. Unlike the No Pit Pond Alternative, if implementation of the dewatering system failed, an estimated 27 to 42 gpm of seepage would eventually leave the pit and migrate into the regional groundwater

system, as described in Section 4.3.4.1.2.2.1 for the Partial Pit Backfill With Downgradient Collection Alternative.

4.4.3.8.2 Potential for Future Liabilities for GSM

Under the Partial Pit Backfill With In-Pit Collection Alternative, the potential for water quality degradation outside of the pit would be increased if the dewatering system failed. The water table would be kept as close as possible to the 4,525-foot elevation by pumping. Untreated water escaping the pit would be the same as under the No Pit Pond Alternative. If the dewatering system failed due to backfill settling and damage to wells, they could be re-established by drilling new wells in the deeper backfill and replacing the pumps. Completion of these wells would be problematic. Safe access to the dewatering system for operation and maintenance would not be a problem because there would be no pit or highwall.

Removing water from up to 875 feet of backfill would be more difficult because of the 47,000,000 cubic yards of backfill material from which the water would be pumped and the 875-foot depth of the wells. Pumps and other dewatering system components would fail regularly from backfill settling and corrosion, as described in Section 4.2.1.5.2. This alternative may create a larger liability for the company in the future because of the uncertainty of pit water quality and complete collection of the water in the pit (GSM, 2002a).

4.4.4 Partial Pit Backfill With Downgradient Collection Alternative

The socioeconomic impacts of the Partial Pit Backfill With Downgradient Collection Alternative are nearly identical to those of the Partial Pit Backfill With In-Pit Collection Alternative.

4.4.4.1 Safety

4.4.4.1.1 Risk to Workers (Reclamation and Construction)

Under the Partial Pit Backfill With Downgradient Collection Alternative, separate placement of sump material in the bottom of the pit would not be required. All pit backfilling to the average elevation of 5,400 feet would be accomplished by hauling and end dumping waste rock from the East Waste Rock Dump Complex from the pit rim. This is the standard method used during mining to create waste rock dumps and has less risk than hauling loaded trucks to the bottom of the pit.

The pit highwall would be reduced to a 2H:1V slope above the 5,400-foot elevation as described in the Partial Pit Backfill With In-Pit Collection Alternative and the risk to worker safety would be the same. Dewatering wells and collection facilities would be constructed outside the perimeter of the backfilled pit. This would be safer for maintenance workers after mining. Reclamation and construction activities would be the same as the Partial Pit Backfill With In-Pit Collection Alternative.

4.4.4.1.2 Risk to Workers (Long-Term Maintenance)

Under the Partial Pit Backfill With Downgradient Collection Alternative, long-term access to the pit bottom would not be required. Worker safety over the long term relates primarily to monitoring and maintenance of the reclaimed pit slopes and benches and the dewatering system. The risk to worker safety in this alternative would be less than the No Pit Pond Alternative and essentially similar to the Partial Pit Backfill With In-Pit Collection Alternative.

4.4.4.1.3 Risk to Public Safety

Access restrictions and risk to public safety would be the same as under the Partial Pit Backfill With In-Pit Collection Alternative.

4.4.4.2 Mining Employment

4.4.4.2.1 Potential Employment from Mining Stage 5B

Employment and income impacts associated with mine operation under the Partial Pit Backfill With Downgradient Collection Alternative would be the same as under the Partial Pit Backfill With In-Pit Collection Alternative.

4.4.4.3 Reclamation Employment

4.4.4.3.1 Reclamation Employment Opportunities

Employment and income impacts associated with pit reclamation under the Partial Pit Backfill With Downgradient Collection Alternative would be essentially the same as under the Partial Pit Backfill With In-Pit Collection Alternative.

4.4.4.4 Revenue from Taxes

4.4.4.4.1 Potential Tax Revenues from Mining Stage 5B

Revenue from taxes associated with mine operations under the Partial Pit Backfill With Downgradient Collection Alternative would be the same as under the Partial Pit Backfill With In-Pit Collection Alternative.

4.4.4.4.2 Potential Tax Revenues from Pit Backfill

Revenue from taxes associated with pit reclamation under the Partial Pit Backfill With Downgradient Collection Alternative would be the same as under the Partial Pit Backfill With In-Pit Collection Alternative.

4.4.4.5 Mineral Reserves and Resources

4.4.4.5.1 Access to Future Mineral Reserves/Resources

This alternative has an additional impact on access to future mineral reserves and resources compared to the Partial Pit Backfill With In-Pit Collection Alternative. In the Partial Pit Backfill With Downgradient Collection Alternative, the backfill would not be dewatered and the water table would rebound. More of the backfill would have to be dewatered as mining proceeds as described in the Partial Pit Backfill With In-Pit Collection Alternative. The agencies assume that a similar dewatering system as used in the Partial Pit Backfill With In-Pit Collection Alternative would have to be installed to dewater to facilitate removal of the backfill. Since there would be no sump material in the bottom of the pit, the dewatering might be less effective. Because there would be no previous dewatering activities, the time required to install the dewatering system and dewater the pit may be longer than the Partial Pit Backfill With In-Pit Collection

Alternative. In addition, it may be harder to dewater backfilled, weathered waste rock than the original pit rock.

In order to re-open the pit after reclamation is completed under the Partial Pit Backfill With Downgradient Collection Alternative, a mining company would have to remove 47,000,000 cubic yards of backfill and soil, which includes the amount needed to re-establish pit benches for access and safety. This would increase the waste-to-ore strip ratio. Up to 735 feet of the backfill would be saturated.

4.4.4.6 Land Use After Mining

4.4.4.6.1 Suitability of Land Use After Mining

The suitability of land use after mining under the Partial Pit Backfill With Downgradient Collection Alternative would be essentially the same as under the Partial Pit Backfill With In-Pit Collection Alternative. Collection of contaminated water outside the pit area would require a large number of wells and a more complex collection and conveyance system. This would increase the size of the industrial usage area by 2 acres. In addition, seeps of poor quality water could develop in the area between the pit and the capture wells. The agencies have assumed one new seep would develop as described in Section 4.3.4.2.1.2. The presence of poor quality water and the spread-out nature of the industrial usage areas could impact wildlife usage. Mine operations have had minimal impact on mule deer.

4.4.4.7 Aesthetics

4.4.4.7.1 Visual Contrast with Adjacent Lands

Impacts to visual resources would be the same as the Partial Pit Backfill With In-Pit Collection Alternative.

4.4.4.8 Potential Future Burden

4.4.4.8.1 Potential Future Burden on Society

The complexity of the dewatering and water collection systems and the uncertainty of collecting all pit water would be the largest potential burden on society. Under the Partial Pit Backfill With Downgradient Collection Alternative, these systems would consist of at least 26 capture wells, at least 10 monitoring wells of various depths, and multiple pipelines to the water treatment plant. More wells may be needed based on hydrogeologic studies.

Secure funding and infrastructure are required to collect and treat contaminated water after closure. The principal consequence of failure of this alternative would be undetected or uncaptured discharges of ARD-impacted groundwater from the

backfilled pit, which could adversely impact springs and beneficial uses of the Jefferson River alluvial aquifer. Total pit seepage of 27 to 42 gpm would reach the regional groundwater system compared to less than 4.2 gpm in the alternatives that maintain the pit as a hydrologic sink. Ninety-six percent of the seepage would have to be collected to prevent water quality impacts at the mixing zone boundary, as described in Section 4.3.4.2.2. Ninety-six percent capture efficiency may not be achievable, as described in Section 4.2.3.1.2. Based on their experience, the agencies believe a maximum capture efficiency of 80 percent per system is potentially achievable.

4.4.4.8.2 Potential for Future Liabilities for GSM

Under the Partial Pit Backfill With Downgradient Collection Alternative, the potential for water quality degradation outside of the pit would be increased. The water table would not be kept below the 5,260-foot elevation equilibrium level by pumping. Therefore, from 27 to 42 gpm of untreated water would escape the pit. Multiple wells would be located down gradient of the pit area to try to capture contaminated groundwater leaving the pit. If the dewatering system failed to capture 96 percent of the groundwater, groundwater standards for some constituents would be exceeded at the edge of the mixing zone (Telesto, 2003e, 2006).

The quality of the water collected down gradient of the pit would be partially attenuated and mixed with regional groundwater. Pumps and other dewatering system components would not fail as regularly due to settling and corrosion. Scaling and biofouling could increase because the water would be collected down gradient of the pit and have a higher pH. Experience at GSM has shown this not to be a problem. Complete capture of pit seepage would not be possible. Ninety-six percent capture efficiency may not be achievable, as described in Section 4.2.3.1.2. Based on their experience, the agencies believe a maximum capture efficiency of 80 percent per system is potentially achievable.

4.4.5 Underground Sump Alternative

The socioeconomic impacts of the Underground Sump Alternative are nearly identical to those of the No Pit Pond Alternative. The principal difference is that pit closure would be confined to reestablishing access, adapting the underground workings, and preparing the underground sump.

4.4.5.1 Safety

4.4.5.1.1 Risk to Workers (Reclamation and Construction)

The Underground Sump Alternative would have less potential for safety liabilities than the No Pit Pond Alternative as it requires workers to maintain access into the pit and to the 4,550-foot-elevation portal, and to maintain the underground workings. Most dewatering equipment would be stationed inside the underground workings. Rock hazards in the underground workings would be added to the risk from highwall rock hazards. However, the agencies agree that the risk of working on the pit floor would be greater than the risk of working in the underground workings.

The lowest stope in the underground workings would be used as a sump in the dewatering system for Stage 5B. During Stage 5B, most of the underground workings would be mined out. After Stage 5B is completed, access to the underground workings would be reestablished by developing a portal at the 4,550-foot elevation. The operational dewatering system in the underground workings would be redesigned for long-term use as described in Section 2.4.5.3. Under the Underground Sump Alternative, workers would re-enter the underground workings to evaluate wall and ceiling stability. Dewatering system construction workers would be exposed to rock falls from the walls and ceiling. Wall and ceiling stability would be monitored and repairs made as needed to ensure worker safety and the integrity of the dewatering system. The agencies would require GSM to develop a long-term plan to stabilize and maintain the ceiling and walls of the underground workings, especially the stopes, where necessary to ensure employee safety.

Pit reclamation and construction under the Underground Sump Alternative would take 24 person years and complete mine reclamation would take about 124 person years.

4.4.5.1.2 Risk to Workers (Long-Term Maintenance)

Risk to worker safety over the long term would be less than the No Pit Pond Alternative. The risks of working underground are less than the risks of working in the bottom of the pit.

4.4.5.1.3 Risk to Public Safety

Access restrictions to the pit area on general public use would be the same as under the No Pit Pond Alternative.

4.4.5.2 Mining Employment

4.4.5.2.1 Potential Employment from Mining Stage 5B

Employment and income impacts associated with mine operation under the Underground Sump Alternative would be the same as under the No Pit Pond Alternative.

4.4.5.3 Reclamation Employment

4.4.5.3.1 Reclamation Employment Opportunities

Employment and income impacts associated with pit reclamation under the Underground Sump Alternative would be essentially the same as under the No Pit Pond Alternative.

4.4.5.4 Revenue from Taxes

4.4.5.4.1 Potential Tax Revenues from Mining Stage 5B

Revenue from taxes associated with mine operation under the Underground Sump Alternative would be the same as under the No Pit Pond Alternative.

4.4.5.4.2 Potential Tax Revenues from Pit Backfill

Revenue from taxes associated with pit reclamation under the Underground Sump Alternative would be essentially the same as under the No Pit Pond Alternative.

4.4.5.5 Mineral Reserves and Resources

4.4.5.5.1 Access to Future Mineral Reserves/Resources

Under the Underground Sump Alternative, no backfill would be placed in the pit. The 200,000 cubic yards (300,000 tons) of pit highwall rock that would ravel or slough over time would have to be removed as part of the future mining plan. The pit bottom would remain dry except after precipitation events while water is infiltrating into the underground workings. A dewatering system would be in place removing pit water from the underground workings. The overall impacts to access to future mineral reserves and resources would be similar to the No Pit Pond Alternative, and 111,000 cubic yards (167,000 tons) less material would have to be removed, adding little to the waste-to-ore strip ratio.

4.4.5.6 Land Use After Mining

4.4.5.6.1 Suitability of Land Use After Mining

Suitability of land use after mining would be the same as the No Pit Pond Alternative.

4.4.5.7 Aesthetics

4.4.5.7.1 Visual Contrast with Adjacent Lands

Impacts to visual resources would be the same as the No Pit Pond Alternative.

4.4.5.8 Potential Future Burden

4.4.5.8.1 Potential Future Burden on Society

For the Underground Sump Alternative, the dewatering system would consist of an underground sump, a powerline, and a series of pumps and pipelines to the water treatment plant. The Underground Sump Alternative would have no water leaving the pit bottom to the regional groundwater system even though the pit water table would be lowered 25 to 75 feet compared to the No Pit Pond Alternative.

The consequence of failure of a dewatering system in the underground workings in this alternative would be that the underground workings below the pit would flood and the pit would begin to fill with water after a period of time. The consequence of failure would be similar to the Pit Pond Alternative, which was dismissed in Section 2.5.4, and the No Pit Pond Alternative. Under the Pit Pond Alternative, the water table would rise to the 4,635-foot elevation and stabilize. Under the Underground Sump Alternative, the agencies expect that up to 200,000 cubic yards (300,000 tons) of rock would ravel and slough off the pit highwall over time. Even with the 200,000 cubic yards (300,000 tons) of rock in the pit bottom, the water level would stabilize below the 5,050-foot elevation. No water would leave the pit. If the dewatering system failed and a pit pond formed, water could be treated in the pit, pumped to the treatment plant from the pit pond, or the No Pit Pond Alternative could be implemented as a contingency. The agencies believe this alternative offers the most flexibility for future changes in water treatment methods.

4.4.5.8.2 Potential for Future Liabilities for GSM

Under the Underground Sump Alternative, the potential for water quality degradation outside of the pit would be limited. The water level, with pit highwall rock that has sloughed to the pit bottom over time, would not reach the 5,050-foot elevation. No untreated water would leave the pit.

In addition, if the dewatering system failed for any reason, it could be re-established in the underground workings more easily than under the partial pit backfill alternatives. Continued safe access to the dewatering system for operation and maintenance under the Underground Sump Alternative would be less difficult than the No Pit Pond Alternative, as described in Section 4.4.5.1.2.

Raveling and sloughing of the highwall would require construction of a new portal at a higher elevation to maintain access to the underground sump and a secondary escape way over time. Removing water from the underground sump would be easier than pumping out of backfill. GSM contends that this alternative would have the least liability in the future (GSM, personal communication, 2003).

4.5 PROJECT ECONOMICS

4.5.1 Reclamation Costs

The estimated capital and operating costs for GSM to complete the pit reclamation by alternative are presented in Table 4-11.

Cost assumptions are based on $1.30 per cubic yard for earthwork, 22 cents per cubic yard for cast blasting, and 27 cents per yard for dozing the blasted material. Revegetation is based on a cost of $385 per acre, and the 53 acres of pit and associated pit reclamation common to all alternatives are included. The backfill costs were produced for alternative comparison purposes. The partial pit backfill alternatives do have costs for repairing future settling. This cost is hard to predict, but 15 percent has been added to the total cost of these alternative closure plans. These costs were estimated for presenting a relative comparison of alternatives.

Table 4 - 11. Reclamation Costs[1] by Alternative

COST CATEGORY	ALTERNATIVE			
	No Pit Pond	Partial Pit Backfill With In-Pit Collection	Partial Pit Backfill With Downgradient Collection	Under-ground Sump
Haul and Place Backfill in the Sump	$288,000	$288,000	$0	$0
Haul and Place Backfill in the Pit to Free Drain	$0	$43,160,000	$43,290,000	$0
Cast Blast the Highwall	$0	$2,618,000	$2,618,000	$0
Dozer Push the Highwall	$0	$643,000	$643,000	$0
Haul and Place Soil Cover on Revegetated Acres	$378,000	$3,469,000	$3,469,000	$371,000
Construct Storm Water Diversion Structures	$0	$335,000	$335,000	$0
Construct/Reclaim Additional Roads/Miscellaneous Disturbance	$0	$83,000	$83,000	$0
Revegetation	$20,000	$112,000	$112,000	$20,000
Dewatering System Installation	$28,000	$310,000	$470,000	$780,000
QA/QC, Supervision, Miscellaneous, Taxes, Insurance	$77,000	$4,337,000	$4,337,000	$82,000
TOTAL COST	$791,000	$55,355,000	$55,357,000	$1,253,000

[1] Costs (in 2003 dollars) based on GSM experience and SEIS contractor experience at Zortman/Landusky mines. Agency costs would be higher.

4.6 REGULATORY RESTRICTIONS ANALYSIS

In 1995, the Montana Legislature amended MEPA to require Montana state agencies to evaluate in their environmental documents any regulatory restrictions proposed to be imposed on the use of private property (Section 75-1-201(1)(b)(iv)(D), MCA). Alternatives and mitigation measures designed to make the project meet minimum environmental standards with implementation methods specifically required by federal or state laws and regulations are excluded from evaluation under the Implementing Guidelines for Section 75-1-201(1)(b)(iv)(D), MCA. Alternatives and mitigation measures that are court mandated also are excluded; these measures are a result of court interpretation of the minimum environmental standards of existing federal and state statutes.

A regulatory restrictions analysis was performed in the 1997 Draft EIS, Chapter IV, Section IV.N. Included was consideration of the No Pit Pond Alternative and Partial Backfill Alternative, which are similar to the alternatives evaluated in this SEIS. The costs for pit reclamation have been updated and are shown in Table 4-11.

4.6.1 No Pit Pond Alternative (No Action)

The total cost of implementation of the No Pit Pond Alternative is approximately $791,000. This is $54,564,000 less than the cost of the Proposed Action, the Partial Pit Backfill With In-Pit Collection Alternative. All of the mitigations in the No Pit Pond Alternative listed in Section 4.8 would be required to comply with applicable laws and regulations.

4.6.2 Partial Pit Backfill With In-Pit Collection Alternative (Proposed Action)

The total cost of implementation of the Partial Pit Backfill With In-Pit Collection Alternative is approximately $55,355,000. All of the mitigations in the Partial Pit Backfill With In-Pit Collection Alternative listed in Section 4.8 would be required to comply with applicable laws and regulations.

4.6.3 Partial Pit Backfill With Downgradient Collection Alternative

This alternative is a variation on the Partial Pit Backfill With In-Pit Collection Alternative. The total cost of implementation of the Partial Pit Backfill With Downgradient Collection Alternative is approximately $55,357,000. This is virtually the same cost as the Proposed Action, the Partial Pit Backfill With In-Pit Collection Alternative. All of the mitigations in the Partial Pit Backfill With Downgradient Collection Alternative listed in Section 4.8 would be required to comply with applicable laws and regulations.

4.6.4 Underground Sump Alternative

The total cost of implementation of the Underground Sump Alternative is approximately $1,253,000. This is $54,102,000 less than the cost of the Proposed Action, the Partial Pit Backfill With In-Pit Collection Alternative. All of the mitigations in the Underground Sump Alternative listed in Section 4.8 would be required to comply with applicable laws and regulations.

4.7 CUMULATIVE IMPACTS

Cumulative impacts are defined as the impacts that result from the incremental effect of an action, decision, or project when analyzed with respect to other past, present, and reasonably foreseeable future actions. The cumulative impacts of GSM's expansion were analyzed in the 1997 Draft EIS, Chapter IV, Section IV.O. The pit reclamation alternatives evaluated in this SEIS would not add to the cumulative impacts evaluated in 1997.

4.7.1 Past, Present, and Reasonably Foreseeable Future Actions

The agencies have updated the following sections with new information from 1997 through 2006.

4.7.1.1 Montana Tunnels Mine

Montana Tunnels Mining, Inc. (Montana Tunnels) operates a zinc, lead, silver, and gold mine located 45 miles north of GSM, in central Jefferson County, near Jefferson City. Montana Tunnels has revised its mine plan since 1997 and is still operating. A major expansion is anticipated if permitting is approved. The agencies received the application in July 2004 and are preparing an EIS. The new plan would allow active mining to continue through 2011. Mining could continue past this point, either by continuing the open pit operation or by developing an underground mine. If mining continues until at least 2011, potential impacts from the project would be minimal during closure, as GSM would be completing closure during the same time period and the initial layoffs from the mine closure would have already occurred. If closure of the mines were to be initiated concurrently, unemployment in the region could be compounded. Cumulative impacts to tax revenue losses for the county also could occur if the closures coincided. Details of potential concurrent closure of the two mines were evaluated in a Montana Tunnels environmental assessment (DEQ and BLM, 2002).

4.7.1.2 Ash Grove Cement

Ash Grove Cement Co. (Ash Grove) continues to operate quarries to supply limestone, silica, and shale for its cement plant in Montana City. No major changes have occurred since 1998. DEQ has approved a permit consolidation plan to combine Ash Grove's six individual permits into one permit for ease of administration by DEQ and Ash Grove.

4.7.1.3 Montana Resources Continental Pit

Montana Resources in Butte, which operates a copper and molybdenum mine, reopened in November 2003 after a 3-year shut down due to low metal prices and high energy prices. Potential cumulative impacts to regional mining employment are not expected, as Montana Resources intends to continue mining. No cumulative impacts to local government finance are anticipated due to the mine's location in a different county. No new cumulative impacts to other resources would be anticipated due to its distance from GSM.

4.7.1.4 Graymont Limestone Mine and Processing Plant

Graymont Western US, Inc. (formerly Continental Lime, Inc.) continues to operate a limestone mine and kiln producing hydrated lime near Townsend. Graymont is the supplier of lime for pH control in the mill at GSM. Graymont's quarry site is located on lands included in the Montana Army National Guard's (MTARNG) Limestone Hills Training Area. MTARNG has applied for a withdrawal covering the training area to ensure that training activities can continue. MTARNG and BLM are coordinating on preparation of a Legislative Environmental Impact Statement. Graymont plans to expand quarry activities farther to the south in the training range. The overall scope of mining activities would not change, and no new cumulative impacts would be anticipated beyond the additional disturbance.

4.7.1.5 Beal Mountain Mine

Pegasus Gold Corporation went bankrupt in 1998. DEQ and the U.S. Forest Service have been reclaiming the Beal Mountain Mine near Gregson since then. The Forest Service is conducting response activities at the site under the Comprehensive Environmental Response, Compensation and Liability Act with input from a technical working group, including DEQ.

4.7.1.6 Exploration Activity at GSM and Other Locations

GSM conducted limited exploration drilling in 2005 and is in the process of reviewing past exploration data. Once the review of existing and new data is complete, exploration targets could be generated (GSM, personal

communication, 2005). An underground mine was developed and completed in January 2004. The Agencies approved a phase two underground mining plan on August 28, 2006 to allow three new portals. A portion of this additional work includes 12,000 feet of core holes to define known exploration targets below the 5B Pit. The cumulative impacts of potential future mining activities cannot be estimated, although GSM contends there is a large mineral resource remaining after mining Stage 5B. Cumulative impacts of exploration activities are not expected to occur, as there is no planned expansion of mining activities outside of current and permitted disturbances. All disturbance related to past exploration activities has been reclaimed. No other mining companies in the area have proposed exploration activities.

4.7.2 Jefferson Local Development Corporation Use of GSM Facilities After Mining

The agencies have reviewed a proposal from GSM to change the land use on a portion of its operating permit area to a light industrial park. Part of the facilities and land would be made available to Jefferson County. This change in land use and donation to the county would lessen impacts at mine closure. The agencies approved the change in October 2004. GSM has also had discussions involving use of the property for a wind farm.

4.7.3 Past, Present, and Reasonably Foreseeable Future Impacts

The agencies have updated the following sections with new information since 1997.

4.7.3.1 Geology, Minerals, and Paleontology

The cumulative impacts on geology, minerals, and paleontology analyzed in the 1997 Draft EIS, Chapter IV, Section IV.O.3.a would not change as a result of implementing any of the alternatives in this SEIS, even though 56 to 58 additional acres would be disturbed under the partial pit backfill alternatives and the pit would be deepened by 125 feet.

4.7.3.2 Water Resources

The cumulative impacts on water resources analyzed in the 1997 Draft EIS, Chapter IV, Section IV.O.3.b would not change as a result of implementing the No Pit Pond, Partial Pit Backfill With In-Pit Collection, or Underground Sump alternatives, because the updated water balance model shows that less water would need to be treated. The Partial Pit Backfill With Downgradient Collection Alternative would add contaminated water to the groundwater system outside of the pit area, which could also affect surface water quality, as described in Section 4.3.4.2.2.2. Dewatering with downgradient collection wells would lower the

regional groundwater level, further affecting groundwater and surface water around the pit area. This is an unavoidable impact of using a groundwater collection system.

4.7.3.3 Soils and Reclamation

The cumulative impacts on soils and reclamation analyzed in the 1997 Draft EIS, Chapter IV, Section IV.O.3.c would not change as a result of implementing the No Pit Pond and Underground Sump alternatives, because the quantity of soil used would not increase. For the partial pit backfill alternatives, cast blasting to reduce the highwall and construction of additional haul roads to transport backfill material and soil would cause additional disturbance. Soil would be stripped from 56 to 58 acres as a result of cast blasting and haul road construction. Soil salvage would be as deep as possible. Any unsalvageable soil would be lost. Soil would also be salvaged from 31 acres northeast of Tailings Impoundment No. 2 to cover the backfill.

Some soil would be wasted on reclaimed areas where highwall rock would ravel and slough or in areas where backfill settled.

4.7.3.4 Vegetation and Wetlands

The cumulative impacts on vegetation and wetlands analyzed in the 1997 Draft EIS, Chapter IV, Section IV.O.3.d would not change as a result of implementing the No Pit Pond and Underground Sump alternatives, because disturbance area would not increase. For the partial pit backfill alternatives, cast blasting to reduce the highwall, construction of additional haul roads to transport backfill material and soil, and installation of new downgradient wells would disturb about 56 to 58 acres. Native vegetation would be lost. Predominantly non-native vegetation communities would be established after the disturbance is revegetated. In addition, native vegetation would be destroyed on soil borrow areas. Soil would also be salvaged from 31 acres northeast of Tailings Impoundment No. 2 to cover the backfill. The borrow areas would be reclaimed with predominantly non-native vegetation. No new wetlands would be disturbed under any of the alternatives.

4.7.3.5 Wildlife and Fisheries Resources

The cumulative impacts on wildlife and fisheries resources analyzed in the 1997 Draft EIS, Chapter IV, Section IV.O.3.e would not change as a result of implementing any of the alternatives in this SEIS, because fewer acres would be disturbed and fewer acres would be reclaimed as highwalls. Wildlife habitat impacts are evaluated under Land Use After Mining sections in each alternative.

4.7.3.6 Threatened, Endangered, and Candidate Species

The cumulative impacts on threatened, endangered, and candidate species analyzed in the 1997 Draft EIS, Chapter IV, Section IV.O.3.f would not change as a result of implementing any of the alternatives in this SEIS, even though 87 to 89 new acres would be disturbed in the partial pit backfill alternatives, because there are still no threatened, endangered, or candidate species on the mine site.

4.7.3.7 Air Quality

The cumulative impacts on air quality analyzed in the 1997 Draft EIS, Chapter IV, Section IV.O.3.g would not change as a result of implementing any of the alternatives in this SEIS, because there would be less disturbance and no change in mining rate.

4.7.3.8 Land Uses and Plans

The cumulative impacts on land uses and plans analyzed in the 1997 Draft EIS, Chapter IV, Section IV.O.3.h would not change as a result of implementing any of the alternatives in this SEIS, because there have been no changes in land uses or plans.

4.7.3.9 Aesthetic Resources

4.7.3.9.1 Visual Resources

The cumulative impacts on visual resources analyzed in the 1997 Draft EIS, Chapter IV, Section IV.O.3.i would not change as a result of implementing any of the alternatives in this SEIS, because fewer acres would be disturbed and fewer acres would be reclaimed as highwall. A mitigation has been added that would produce more reclamation of the upper pit highwalls to reduce visual contrast in the No Pit Pond and Underground Sump alternatives. Another mitigation has been added to extend the East Waste Rock Dump Complex across the pit mouth to obscure part of the pit highwall.

4.7.3.9.2 Noise

The cumulative impacts on noise analyzed in the 1997 Draft EIS, Chapter IV, Section IV.O.3.i would not change as a result of implementing any of the alternatives in this SEIS, because there would be no new sources of noise or increases in mining activity.

4.7.3.10 Socioeconomic Resources

The cumulative impacts on socioeconomic resources analyzed in the 1997 Draft EIS, Chapter IV, Section IV.O.3.j would not change as a result of implementing any of the alternatives in this SEIS unless GSM closed prematurely, then the impacts of closure would occur sooner.

4.7.3.11 Hazardous Materials and Wastes

The cumulative impacts associated with hazardous materials use and storage at the site, analyzed in the 1997 Draft EIS, Chapter IV, Section IV.O.3.k, would not change as a result of implementing any of the alternatives in this SEIS.

4.7.3.12 Cultural Resources

The cumulative impacts on cultural resources analyzed in the 1997 Draft EIS, Chapter IV, Section IV.O.3.l could change as a result of implementing any of the partial pit backfill alternatives in this SEIS. A cabin located near the highwall could be damaged or destroyed when the highwall is cast blasted.

4.7.3.13 Native American Concerns

The cumulative impacts on Native American concerns analyzed in the 1997 Draft EIS, Chapter IV, Section IV.O.3.m would not change as a result of implementing any of the alternatives in this SEIS, because no cultural resources would be disturbed.

4.8 AGENCY MITIGATION MEASURES

Mitigation measures for the mining operations at GSM were identified in the 1997 Draft EIS, Chapter IV, Section IV.P. Only mitigation and monitoring that could be implemented to mitigate potential impacts from the pit reclamation alternatives being evaluated in this SEIS are discussed in this section.

4.8.1 Technical Issues

4.8.1.1 Pit Highwall

Issue: Pit highwall stability under alternatives that do not require partial pit backfilling.

Measure 1: A plan for monitoring and mitigating raveling and sloughing of the pit highwall would be developed and implemented after closure. Survey prisms currently used to ensure safe mining operations would continue to be used after closure during activities in the pit to monitor ground movement in potentially susceptible areas. A plan concerning entry into the pit after storm events, spring thaws, or after long periods of absence would also be developed.

Horizontal drains and highwall dewatering wells would be maintained and new ones installed where necessary to relieve hydrostatic pressure in the highwall and capture groundwater before it enters the pit.

Effectiveness: These measures have been proven to be effective during the past 25 plus years of mining at GSM. These plans would help ensure workers' safety and provide for a mechanism to help maintain pit access. The wells would help reduce the amount of pit water that would have to be handled.

Application: This measure would apply to the No Pit Pond Alternative and the Underground Sump Alternative.

4.8.1.2 Backfill

Issue: Backfill maintenance.

Measure 2: Backfilled areas would be monitored for settling. If ponding occurred, more soil would be placed to restore the gradient. Gradients would be monitored for settlement along storm water diversions that could result in erosion on the face of the revegetated slopes. Storm water diversion gradients on the backfill would be reestablished as needed and any erosion damage would be repaired.

Small localized failures could develop because highwall seeps could flow laterally through and saturate the cover. Seep water would be acidic and would contaminate soils and impair revegetation success if allowed to contact the soil cover. To improve soil cover stability in these localized areas after a failure, the seep would be located and dewatered, contaminated soil would be replaced with clean soil, and the area would be revegetated.

GSM would backfill the underground workings remaining after Stage 5B to minimize settlement in the partial pit backfill alternatives. The lowest stope in the underground workings would be maintained as a contingency dewatering sump in the No Pit Pond Alternative.

Effectiveness: There would be less need for backfill maintenance, and there would be fewer dewatering well failures because of backfill settlement. Localized failures of overhead rock in the underground workings over time could result in subsidence, especially in seep and fault areas where chemical weathering would be increased. This subsidence could cause the backfill to further settle, potentially affecting the dewatering wells in the backfill.

Application: This measure would apply to all alternatives except the Underground Sump Alternative.

Issue: Backfill source.

Measure 2a: Backfill would be obtained from along the northeastern edge of the East Waste Rock Dump Complex, instead of from the top. The original Sheep Rock drainage would be uncovered, and 67 acres of waste rock dump would be removed and placed back into the pit (Figure 4-3). The return diversion around the East Waste Rock Dump Complex would be blocked and reclaimed. This measure applies to both partial pit backfill alternatives. The final configuration of the East Waste Rock Dump under the Underground Sump and No Pit Pond alternatives is shown on Figure 4-4.

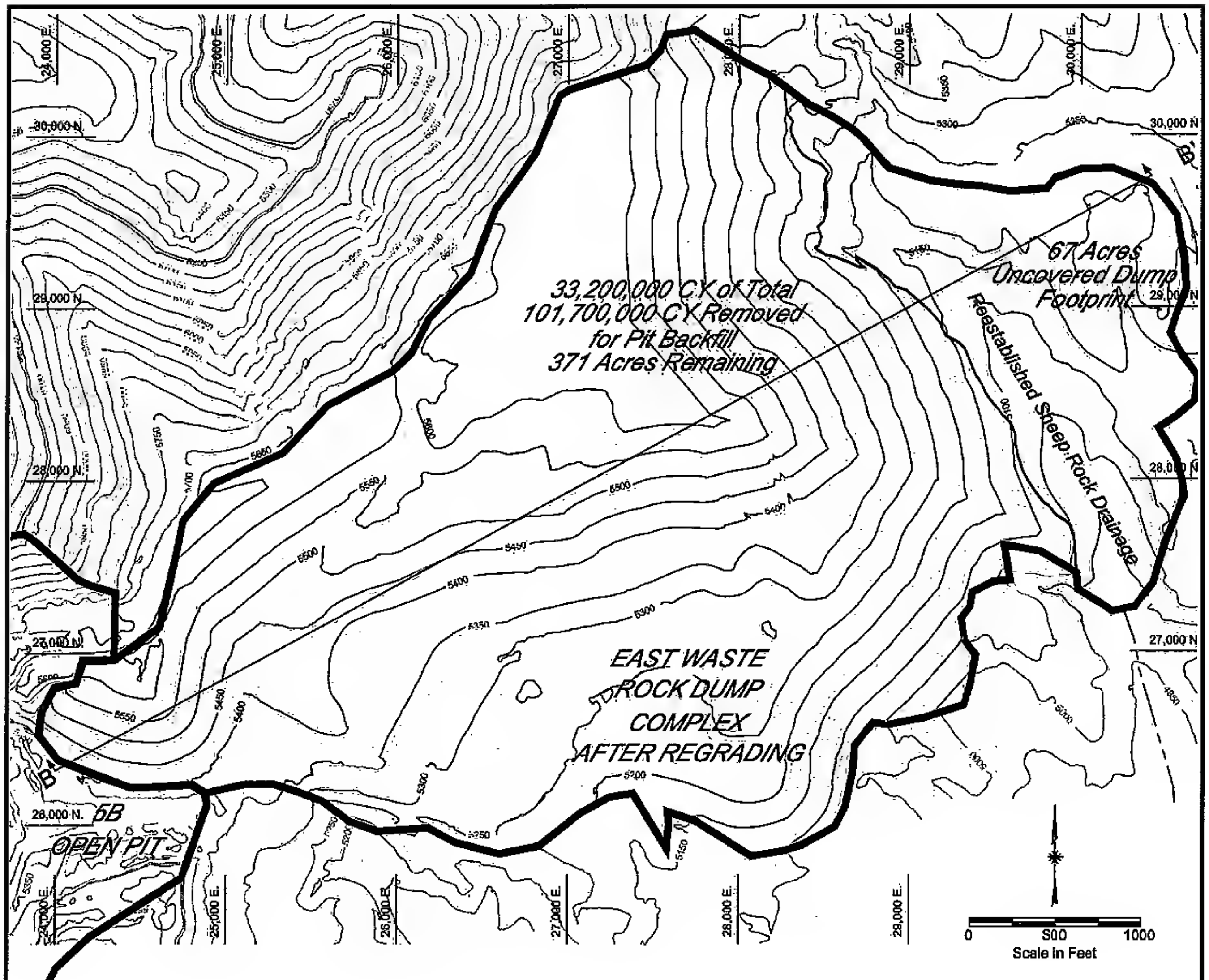
Effectiveness: This measure would reduce the footprint of the East Waste Rock Dump Complex by 67 acres and re-establish the Sheep Rock drainage.

Application: This measure would apply to the partial pit backfill alternatives.

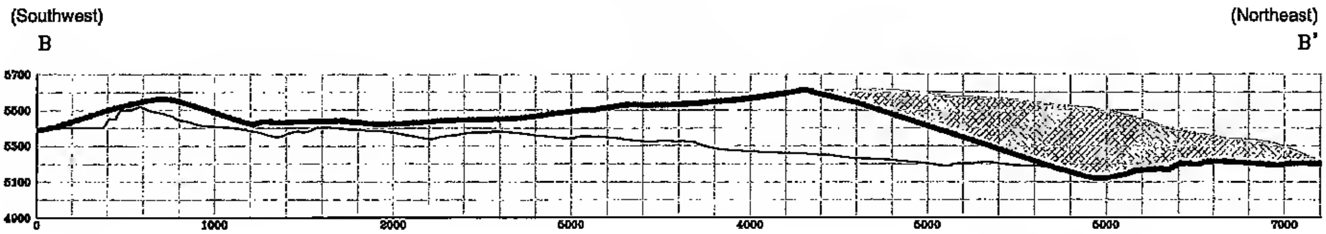
4.8.1.3 Groundwater Effluent Management System

Issue: Identification of secondary flow paths from the pit.

Measure 3: This is a modification of Measure W-10 from the 1997 Draft EIS, Chapter IV, Section IV.P, which was approved as Stipulation 010-13 in the 1998 ROD.



CROSS SECTION



LEGEND

- Pre-Mining Topography
- Regraded Topography
- East Waste Rock Dump Complex Removed For Partial Pit Backfill Alternatives

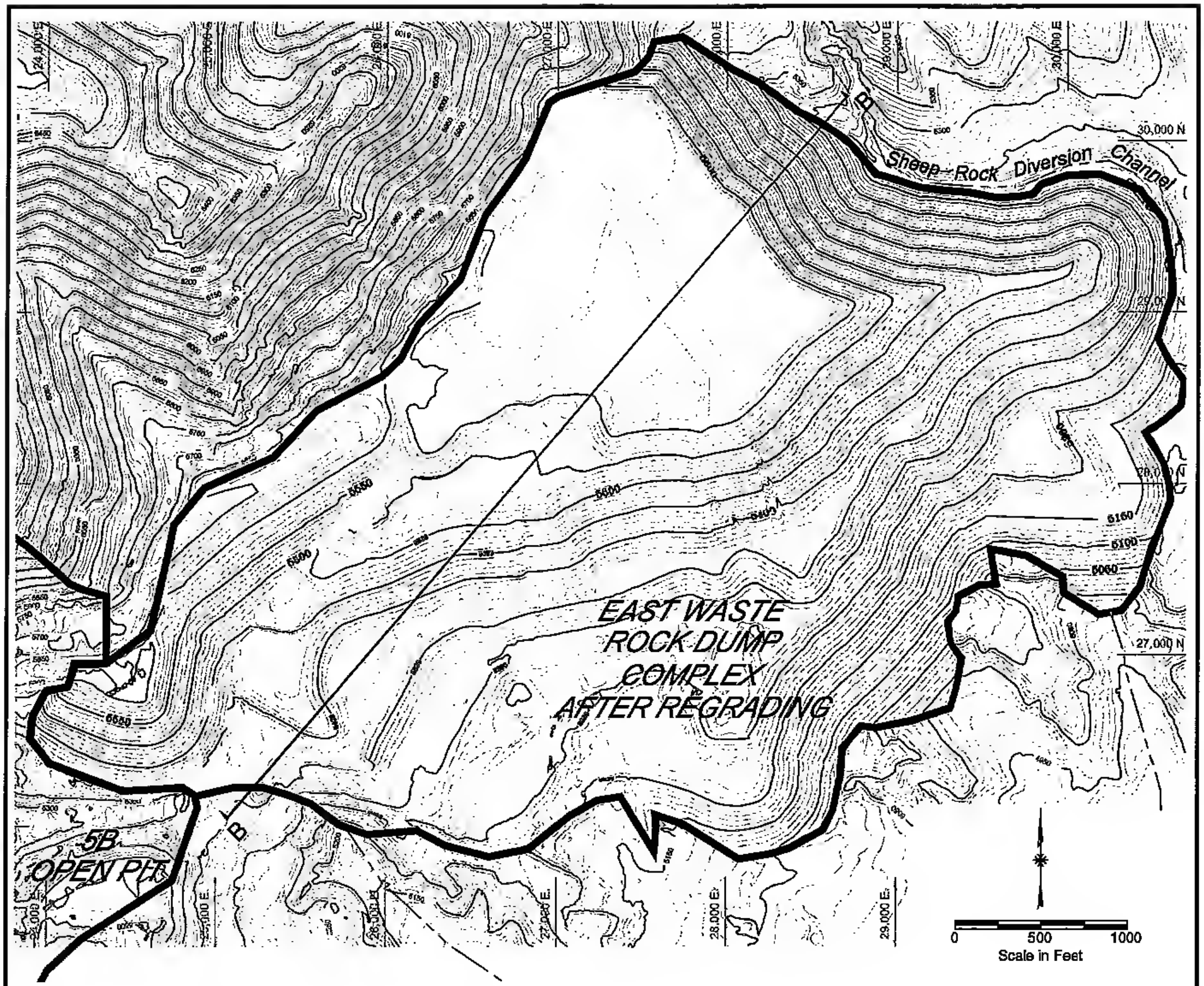
0 500 1000
Horizontal & Vertical
Scale in Feet

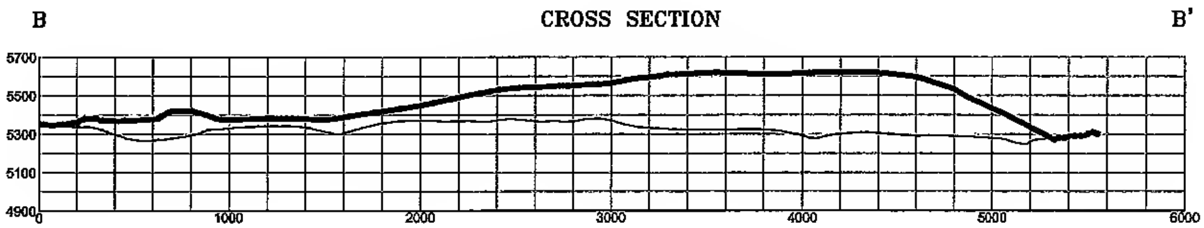
Partial Pit Backfill Alternatives

REGRADED EAST WASTE ROCK DUMP COMPLEX TOPOGRAPHY AFTER PARTIAL PIT BACKFILL AFTER MITIGATION

Figure 4-3 mitig PPB rockdump-xsec.dwg

FIGURE 4-3





LEGEND

Pre-Mining Topography

Regraded Topography

0 500 1000
Horizontal & Vertical
Scale in Feet

No Pit Pond & Underground Sump Alternatives

REGRADED EAST WASTE ROCK DUMP COMPLEX TOPOGRAPHY AFTER MITIGATION

Figure 4-4 mitig Rockdump-xsec.dwg

FIGURE 4-4

A hydrogeologic investigation would be conducted down gradient of the pit to identify geologic structures that could act as secondary groundwater flow paths east, west, and south of the pit for purposes of monitoring and future groundwater capture of pit seepage. The study would be comprised of geologic mapping, test well drilling, and aquifer testing. The results of the study would be used to determine optimum groundwater monitoring locations and to design a groundwater capture system to minimize impacts to beneficial water uses from pit seepage.

Groundwater capture wells would be installed on secondary pathways when monitoring indicates a need. Based on previous studies of groundwater capture in bedrock and experience in drilling wells at GSM, it is estimated that at least two capture wells would initially be required for each structure with evidence of ARD migration. Testing and monitoring would be required to determine whether two wells achieved sufficient capture efficiency. Existing and potential monitoring and capture well locations are listed in Table 4-12 and shown on Figure 4-5 in the SEIS.

Effectiveness: A hydrogeological investigation to identify secondary flow paths down gradient of the pit would increase the efficiency of the proposed groundwater capture systems. Wells installed as a result of this study would reduce the problem of complying with applicable groundwater quality standards and would protect springs and beneficial uses of the Jefferson River alluvial aquifer.

Application: This measure would apply to the Partial Pit Backfill With Downgradient Collection Alternative.

Issue: Dewatering system damage from highwall raveling and sloughing.

Measure 4: As a contingency in case the dewatering system were damaged, destroyed, or became inaccessible, the agencies would require GSM to submit a plan for development, maintenance, and monitoring of a portal at a suitable elevation to allow access to the underground workings, so that dewatering would still be possible using an underground sump. If the 4,550-foot-elevation portal became inaccessible, GSM would have to establish a third portal.

Effectiveness: This contingency would allow dewatering to continue to keep the water table from rebounding if the dewatering system is damaged or destroyed and cannot be reestablished.

Application: This measure would apply to the No Pit Pond Alternative and the Underground Sump Alternative.

Issue: Access to the dewatering system in the pit.

Measure 5: Highwall safety benches, especially the 5,700-foot safety bench, and safety berms around the pit floor working surface would be maintained to catch rock that ravels and sloughs from the highwall after closure. The pit haul road would be maintained for access. Rock raveling and sloughing from the highwall and escaping the safety benches and berms would be removed. For the No Pit Pond Alternative, the working surface on the pit floor would be graded to remove the rocks, filled with more waste rock to re-level the working area, and resoiled if necessary.

Effectiveness: Maintenance of safety benches, berms, haul road, and the working area in the pit bottom would ensure that the dewatering system in the pit would be accessible, and worker safety would be ensured.

Application: This measure would apply to the No Pit Pond Alternative and the Underground Sump Alternative.

Issue: Dewatering system monitoring.

Measure 6: GSM would install and maintain a remote monitoring system for wells, pumps, pipelines, powerlines, etc., to ensure water is captured efficiently.

A dewatering monitoring system performance program would be implemented to monitor progress of the dewatering, evaluate the effectiveness of the system, and document the volume and quality of water pumped from the pit, underground sump, and capture wells.

Effectiveness: A remote monitoring system would ensure the proper functioning of the dewatering system while protecting workers by not requiring them to visit dewatering system components frequently. The system performance program would track the efficiency of the dewatering system and identify potential for improvement.

Application: This measure would apply to all alternatives.

Issue: Dewatering system failures.

Measure 7: Dewatering wells, pumps, access roads, powerlines, and pipelines would be repaired or replaced as needed to maintain dewatering system operations.

Effectiveness: Maintaining dewatering system components in good order would protect groundwater quality.

Application: This measure would apply to all alternatives.

Issue: Failure of the dewatering system in the Partial Pit Backfill With Downgradient Collection Alternative.

Measure 8: If the Partial Pit Backfill With Downgradient Collection Alternative were selected and the downgradient capture system does not prevent impacts at the mixing zone boundary, dewatering wells would be installed in the backfilled pit as in the Partial Pit Backfill With In-Pit Collection Alternative (see Figure 4-5 for well locations).

Effectiveness: This measure would minimize the potential for pit discharge.

Application: This measure would apply to the Partial Pit Backfill With Downgradient Collection Alternative.

Issue: Access to the underground workings.

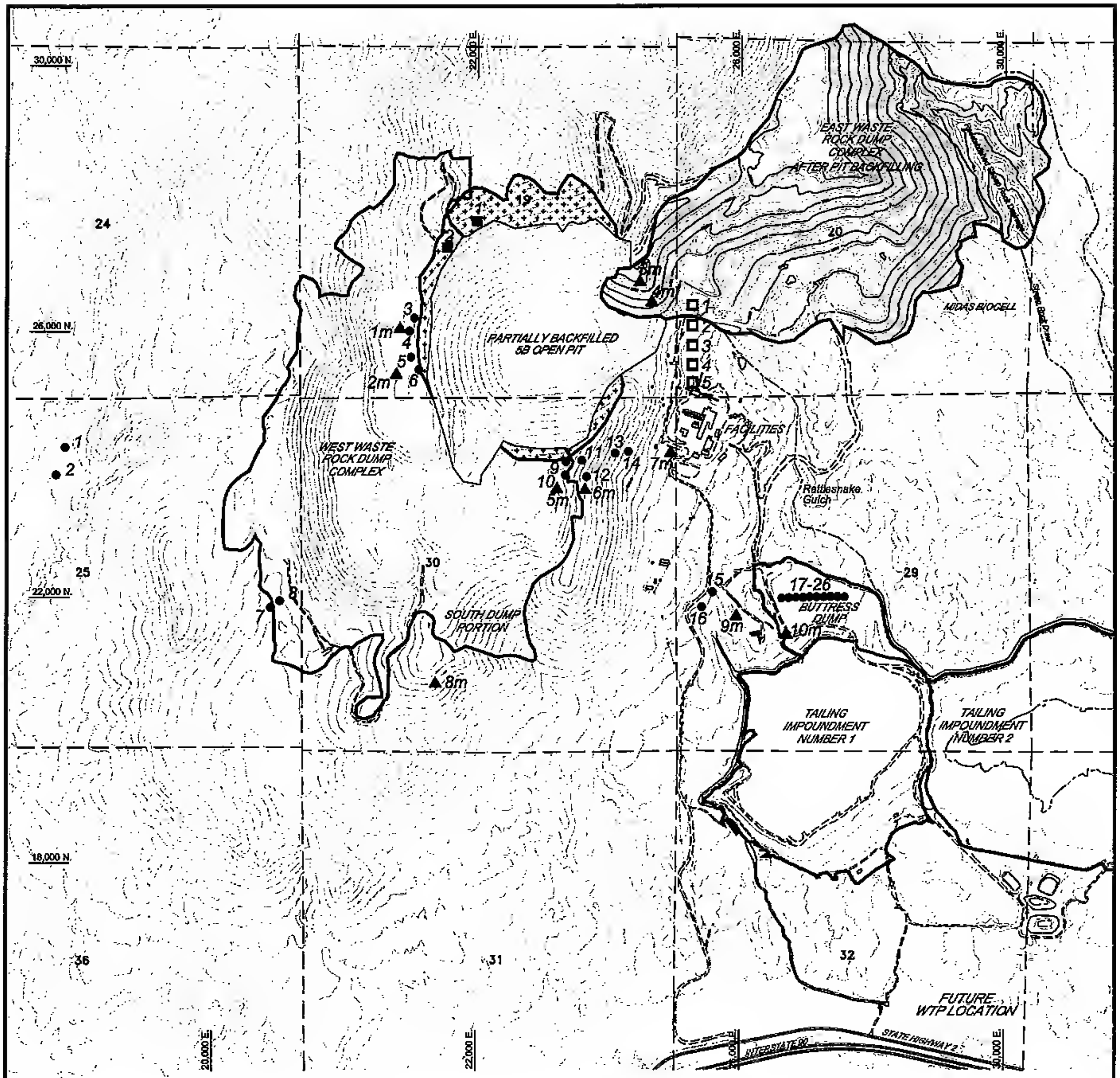
Measure 9: Access to the underground would be needed for a primary or contingency pit dewatering system. The agencies expect that the 4,550-foot elevation portal to the underground workings would be buried by rocks raveling off the highwalls and mass failures over time. The agencies would require GSM to submit a plan for development, monitoring, and maintenance of a new portal at a suitable elevation for access long term. The agencies would bond for maintenance of access and regular repair and replacement of dewatering system components.

This would require additional powerlines, pipelines, and maintenance of access roads in the underground workings to ensure integrity of the dewatering system and provide secondary access for workers. Monitoring of the underground workings would be required to ensure the integrity of the walls and ceiling.

A monitoring and maintenance plan would be needed to ensure continued access to repair the dewatering system and to ensure worker safety. The monitoring and maintenance plan would be applied to both the 4,550-foot and contingency portal locations. If the 4,550-foot-elevation portal became inaccessible, GSM would have to establish a third portal.

Effectiveness: Secondary portals would provide access to the underground workings, a backup dewatering system, and an escape way for workers.

Application: This measure would apply to the No Pit Pond Alternative and the Underground Sump Alternative.



LEGEND

- ■ New Upgradient Well (1-2)
- □ New Near Pit Well (1-5)
- ● New Dewatering Well (1-26)
- ▲ New Monitoring Well (1m-10m)
- Highwall Reduction Area

0 1200 2400
Scale in Feet

Partial Pit Backfill With Downgradient Collection Alternative

POTENTIAL DOWNGRADIENT DEWATERING WELL LOCATIONS AFTER MITIGATION

FIGURE 4-5

Figure 4-5 mitig Downgradient_wells.dwg

4.8.1.4 Storm Water Runon/Runoff Management

Issue: Storm water diversion maintenance.

Measure 10: Storm water diversions would be monitored regularly for integrity and gradient. If the gradient changed from settling resulting in low spots, the diversion would be returned to the proper gradient, resoiled, and seeded as necessary. Eventually, portions of the diversions would need to be reconstructed completely or at least have sediment accumulations and/or rockfalls from upgradient slopes removed.

Effectiveness: The maintenance requirements for the storm water diversions would ensure the ability of the diversions to route water away from the pit area over time.

Application: This measure would apply to all alternatives.

4.8.1.5 Soil Cover

Issue: Monitoring and testing of soils affected by steam venting at the waste rock dump complexes and the reclaimed pit area and tracking number and size of vents on all reclaimed surfaces over acid-producing materials.

Measure 11: This would replace Measure S-1 from the 1997 Draft EIS, Chapter IV, Section IV.P, which was approved as Stipulation 010-14 in the 1998 ROD.

A program would be implemented for the continued monitoring of existing waste rock dump complexes and pit surfaces that are reclaimed over acid-producing materials to further assess the impacts, if any, that steam venting may have on reapplied soil or establishing vegetation. The program would consist of GSM and/or agency reclamation specialists annually monitoring the number, location, and size of steam vents and extent of modified plant communities surrounding vent locations. If detrimental effects to establishing vegetation communities are observed on more than 0.1 percent of the total reclaimed area covering acid-producing materials, GSM would be required to: 1) rock armor vent locations to prevent erosion and spreading of vent locations, 2) sample and test soils at vent locations, and 3) prepare a detailed plan to further reduce the expansion of steam vents and minimize potential impacts to reclamation success. Soil parameters to be tested would correspond to those which appear to have given rise to the change in vegetation communities. At a minimum, soil pH and ABA would be evaluated for each sample collected. The general cost for such a program would be included in a post-mine maintenance bond.

Effectiveness: This would be an effective means of assessing and mitigating the changes occurring, if any, through time to reapplied soil materials and vegetation communities as a result of steam venting. The results of testing would be directly applicable to assessing whether steam venting had a negative effect on establishing vegetation communities.

Application: This measure would apply to all alternatives.

Issue: Pit reclamation maintenance.

Measure 12: Any acreage revegetated in the pit would be monitored for rock raveling and sloughing, backfill settling, erosion, and noxious weeds. Rock that has raveled or sloughed on revegetated areas would be removed or covered with new soil. Areas that have settled would be filled to grade with additional soil. Eroded areas would be repaired, resoiled, and reseeded. Noxious weeds would be controlled.

Effectiveness: This measure would ensure that revegetated areas are maintained, and storm water is diverted out of the pit.

Application: This measure would apply to all alternatives.

Issue: Reclamation soil rock content for 2H:1V slopes.

Measure 13: GSM would perform further testing to verify that soils from the proposed borrow site east of Tailings Impoundment No. 2 has the rock size and characteristics that are adequate for use on 2H:1V slopes. An amendment to add rock fragments would be required if necessary.

Effectiveness: This measure would ensure that soil placed on 2H:1V slopes in the pit would be protected from erosion.

Application: This measure would apply to all alternatives.

4.8.1.6 Water Treatment

Issue: Total of combined inflows to permanent water treatment plant exceeds the capacity of the plant.

Measure 14: This is Measure W-6 from the 1997 Draft EIS, Chapter IV, Section IV.P, which was approved as Stipulation 010-9 in the 1998 ROD.

The capacity of the permanent water treatment plant would be reevaluated and incorporated into the final design within 2 years prior to projected mine closure. At that time, the actual rate and quality of pit inflow during peak flow and low flow

periods, and the total rate and quality of groundwater captured in the tailing area will be better known.

Based on the degree of uncertainty of the rate of inflow from future sources, a contingency measure of up to 25 percent additional flow would be incorporated into the treatment plant capacity, and a contingency to provide storage for up to 6 months of anticipated water inflow would be included. This would provide for time to modify the plant if needed for unanticipated future inflows.

Alternatively, a new, additional water treatment facility would be constructed to address treatment of a specific source or sources. This supplemental water treatment facility would be built at the time such sources are identified. This alternative measure may be considered for treatment of waste rock dump ARD, because the time frame before ARD impacts are anticipated to occur is longer than a reasonable design life of the permanent water treatment plant that will be built at the end of mining.

Effectiveness: Sufficient additional water treatment capacity, whether added to the permanent water treatment plant design or as an additional separate facility, would provide for treatment of unanticipated inflows.

Application: This measure would apply to all alternatives.

4.8.2 Environmental Issues

4.8.2.1 Impacts to Groundwater Quality and Quantity

Issue: Compliance with groundwater standards down gradient of the pit.

Measure 15 from the Draft SEIS has been broken into three parts, based on public comments.

Measure 15a: The Rattlesnake Gulch dewatering wells and Tailings Impoundment No. 1 south pumpback system wells would be operated together to try to achieve at least a 96 percent capture efficiency of groundwater in the Tdf/colluvial aquifer down gradient of the pit to achieve compliance with groundwater standards for nickel and the other metals. If monitoring shows that an overall 96 percent capture is not being achieved, more wells would be installed.

Effectiveness: This measure would minimize impacts to the Jefferson River alluvial aquifer, but it cannot be guaranteed that sufficient wells can be installed to prevent water quality violations.

Application: This measure would apply to the Partial Pit Backfill With Downgradient Collection Alternative.

Measure 15b: Two capture wells would be installed up gradient of the pit to reduce the volume of groundwater entering the pit from the Corridor Fault by at least 15 gpm.

Effectiveness: Upgradient capture wells would reduce the rate of groundwater seepage to the pit by 15 gpm, reducing the expected pit seepage to the Tdf/colluvial aquifer from 27 to 42 to 12 to 27 gpm. If Measure 15a achieves only 92% overall capture efficiency, groundwater standards would be met at the mixing zone boundary if pit seepage rates are less than 16 to 18 gpm under the Partial Pit Backfill With Downgradient Collection Alternative.

Application: Upgradient capture would apply to the partial pit backfill alternatives.

Measure 15c: Five wells would be installed near the eastern edge of the pit in upper Rattlesnake Gulch to capture some of the pit seepage (see Figure 4-6 for well locations). The targets of the capture wells would be the Tdf/colluvial aquifer and the Corridor Fault. A detailed hydrogeologic characterization of the area directly east of the pit would be required to identify the most effective zones for capture.

Table 4 - 12. New Capture Well Locations

Flow Path	Location	No. of Wells	Comments
Corridor Fault	Up Gradient of pit	2	
Tdf/colluvial Aquifer	Down gradient of pit	5	Near east edge of pit in upper Rattlesnake Gulch

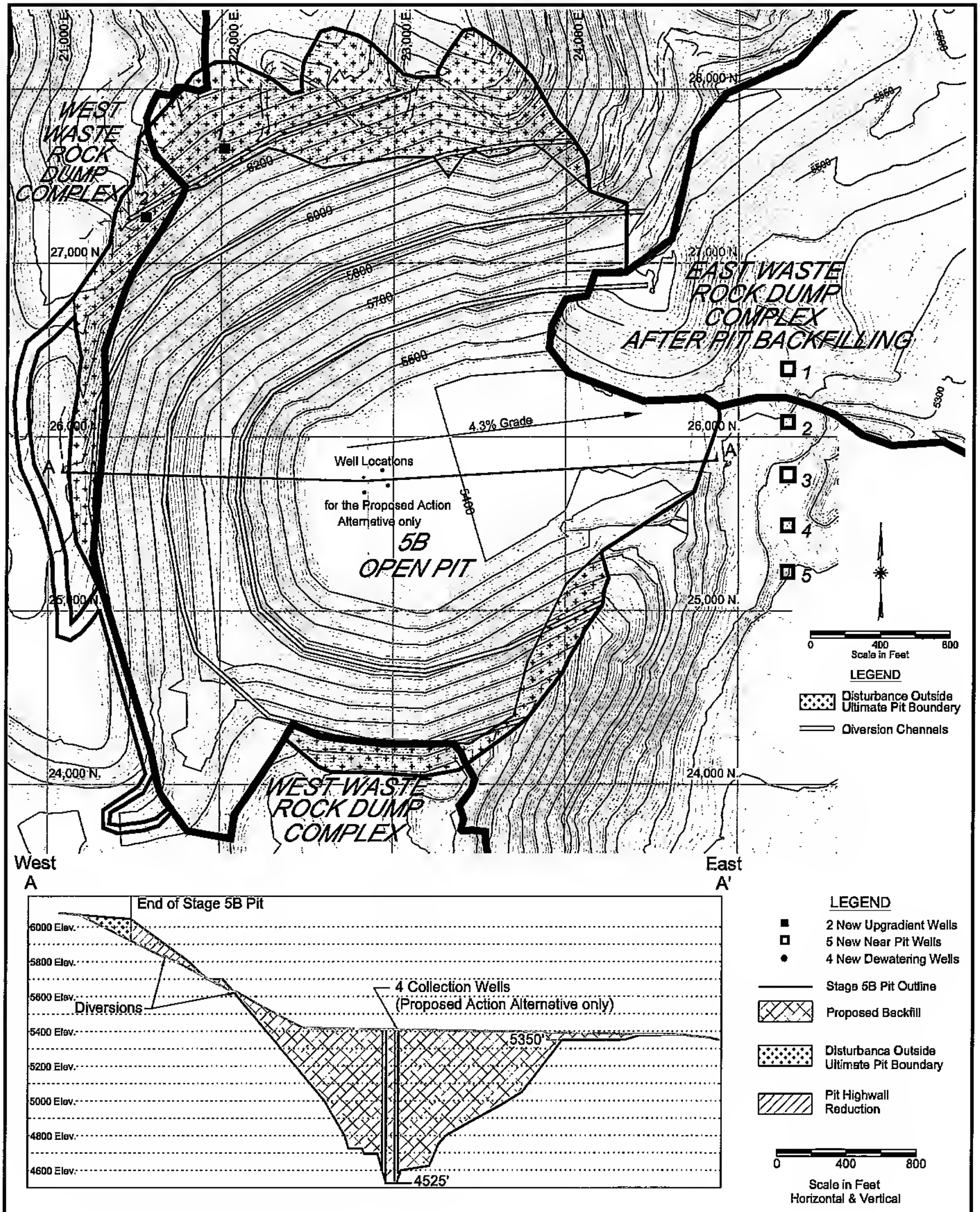
Effectiveness: This measure would reduce some of the water entering the aquifer from the pit. Its effectiveness would be limited because:

- This is a structurally complex aquifer. Groundwater flow is less predictable than in the sedimentary deposits in Rattlesnake Gulch. Groundwater flow could be in fractured rock and might by-pass the Tdf/colluvial aquifer adjacent to the pit;
- The Tdf/colluvial aquifer at this location is deeper and more heterogeneous and has multiple flow paths, making capture more difficult than at the current location of the Rattlesnake Gulch capture system; and
- The groundwater gradient is high. The large groundwater gradient results in less saturated thickness and faster groundwater velocities, making capture in wells more difficult.

Application: This measure would apply to the Partial Pit Backfill With Downgradient Collection Alternative.

Issue: Impacts to beneficial uses in the Jefferson River alluvial aquifer.

Measure 16: Water would be discharged from the permanent water treatment plant back to the aquifer as recharge, or to discharge as surface water in order to minimize impacts to downgradient beneficial uses.



Partial Pit Backfill with In-Pit Collection Alternative would have four 800-875 foot dewatering wells drilled to approximately the 4525-foot elevation. Up to eleven total dewatering wells would be required for mitigation.

Partial Pit Backfill with Downgradient Collection Alternative would have no in-pit wells.

Partial Pit Backfill Alternatives

FINAL PARTIAL PIT BACKFILL CONFIGURATION AFTER MITIGATION

Figure 4-6 mitig PPB-backfill-xsec.dwg

FIGURE 4-6

Effectiveness: This measure would minimize impacts to beneficial uses of water down gradient of the groundwater capture system in the Jefferson River alluvial aquifer or the Jefferson River and Slough.

Application: This measure would apply to all alternatives.

Issue: Modification of the groundwater mixing zone to include pit discharge.

Measure 17: Pit discharge was not included in the groundwater mixing zone statement of basis in the 1998 Final EIS, Appendix 1. The flow paths from the pit are within the permitted GSM mixing zone. GSM would have to submit an application to modify the approved mixing zone. DEQ would modify the 1998 Statement of Basis for the mixing zone.

Effectiveness: The mixing zone analysis and the statement of basis modification would ensure compliance with groundwater quality standards at the mixing zone boundary.

Application: This measure would apply to the Partial Pit Backfill With Downgradient Collection Alternative.

4.8.2.2 Impacts to Surface Water Quality and Quantity

Issue: Identification and replacement of altered discharge or reduced water quality at springs and seeps.

Measure 18: This is a modification of Measure W-1 from the 1997 Draft EIS, Chapter IV, Section IV.P, which was approved as Stipulation 010-4 in the 1998 ROD.

A monitoring program would be established to quantify discharge and water quality at springs in the project area and to identify any reductions or increases in flow or changes in water quality. Data would be collected often enough to detect spring response to seasonal variations and pit dewatering.

Mitigation of reduced discharge at springs would be accomplished by further development of the affected spring or by diverting water from the permanent water treatment plant to provide water for wildlife and livestock use. Further development of the spring would involve improving collection and storage of spring discharge and/or expanding the interception area of the spring at the water table.

Mitigation would be required if spring discharge increased by more than 15 percent of the baseline spring flow or if water quality declined. If flow increased

or water quality decreased, the spring water would be collected and routed to the water treatment plant for treatment and disposal.

Mitigation of reduced water quality would be accomplished by establishing additional water sources for wildlife and livestock use. Treated water from the permanent water treatment plant would be discharged as surface water for wildlife and livestock use.

Any change in the quantity and/or quality of springs and seeps, and their associated source of contaminants, would be subject to an MPDES permitting review by DEQ. For bonding purposes, under the Partial Pit Backfill With Downgradient Collection Alternative, the agencies have assumed that one existing spring, Stepan Spring, would have a 15 percent increase in flow that would have to be collected and treated, and that one new spring discharging 1.5 gpm would develop and would be collected and treated under an MPDES permit.

Effectiveness: This measure would document variations in spring discharge and spring water quality and provide data to determine if changes in spring flows or water quality occur during and after mining. This measure also would provide continued surface water sources at the mine site, reducing impacts to wildlife and livestock.

Application: This measure would apply to all alternatives.

Issue: ARD release from waste rock dump complexes or the pit area that is either premature because of transport along preferential, discrete flow paths and/or of greater flow rate than modeled performance because of higher than expected infiltration.

Measure 19: This is Measure W-4 from the 1997 Draft EIS, Chapter IV, Section IV.P, which was approved as Stipulation 010-7 in the 1998 ROD.

If the data from existing monitoring wells and/or spring flows indicate that changes in water quality are occurring which are likely to exceed applicable regulatory requirements, the following mitigation measures would be employed:

a) If water quality impacts are detected in monitoring wells at the mixing zone boundary down gradient from the East Waste Rock Dump Complex, localized capture of groundwater may be needed to contain ARD transport along preferential, discrete flow paths that were not anticipated by the ARD fate and transport model (see the 1997 Draft EIS, Appendix J). A groundwater capture system similar to the system described in Appendix A for the West Waste Rock Dump Complex would be installed. Capture of discrete plumes from the East Waste Rock Dump Complex would not require a well system as extensive as that needed for the West Waste Rock Dump Complex. The contingency design in the 1997 Draft EIS, Appendix A that provides for treatment of approximately 20

percent of the predicted flux on the east side is considered adequate for this mitigation measure;

b) ARD-impacted seeps may emerge at the toes of the waste rock dumps where preferential drainage paths occur within the dumps that lead to discrete "perched" saturated zones at their base. Shallow groundwater capture systems such as toe drains around the peripheries of the waste rock dumps would be installed to supplement the primary, deep capture well system; or

c) *In-situ* treatment systems would be installed in the shallow ("perched") aquifer zones, including the alluvial materials over bedrock on the west side, and/or the colluvial/alluvial materials in Rattlesnake Gulch or at other locations down gradient of the East Waste Rock Dump Complex. One example of this type of emerging technology is a funnel and gate approach which incorporates groundwater barriers that "funnel" the identified contaminant plume(s) through constrained location(s) within the shallow aquifer. *In-situ* reaction walls, such as limestone-filled trenches, are installed at these "gate" locations. The reaction walls provide essentially "semipervious" barriers which allow water to pass but "filter" the dissolved metals or other contaminants.

Effectiveness: The supplemental groundwater capture systems described would allow interception of contaminated groundwater that bypasses the primary capture well system. ARD-impacted groundwater could bypass the capture wells along shallow perched flow paths around the peripheries of all the dumps, or move through high conductivity preferential flow paths down gradient from the East Waste Rock Dump Complex. The supplemental systems described would provide for capture of these potential ARD sources before the contaminated water migrates down gradient to beneficial uses, or to sensitive receptors, such as the Jefferson River.

Application: These measures would apply to all alternatives.

4.8.3 Socioeconomic Issues

4.8.3.1 Safety

Issue: Worker safety within the pit.

Measure 20: A 70-foot-wide safety bench at the 5,700-foot elevation would be left around three sides of the pit for additional protection. One or more berms would be constructed around the perimeter of the working area on the pit bottom in the No Pit Pond Alternative to trap incidental rocks that may fall from the highwall. The access road leading down to the working surface on the pit bottom from the 4,875-foot elevation would be widened by extending the road to the south over a portion of the 4,800-foot-elevation area and away from the highwall toe.

The agencies would require the development of secondary portals at suitable elevations in the pit as secondary escape ways as needed.

The agencies would require GSM to install and maintain a remote monitoring system for wells, pumps, pipelines, powerlines, etc., to minimize the need for workers to be in the pit.

Effectiveness: These measures would provide additional protection to workers in the pit, but there would continue to be hazards associated with working in the pit.

Application: This measure would apply to the No Pit Pond Alternative and the Underground Sump Alternative.

4.8.3.2 Aesthetics

Issue: Visual contrast with adjacent lands.

Measure 21: About 37 acres in the pit would be treated with the following measures to reduce the visual contrast with adjacent lands, if the work can be accomplished safely:

- End dumping and/or cast blasting would occur along the upper portion of the northwest and west highwalls, and these areas would be seeded and possibly planted with trees.
- Dozer work would be completed on the area of the west highwall that sloughed in 2005 or another appropriate area, and this area would be seeded and possibly planted with trees.
- Soil sampling on the old slide area on the northwest highwall would be completed, and this area would be seeded and possibly planted with trees.

- Soil would be placed on the highwall bench above the 5,700-foot safety bench, and the area would be seeded and planted with trees if it is safe to do so.
- Trees would be planted where possible on the 5,700- and 5,400-foot safety benches.

Effectiveness: Sharp lines and forms in the pit would be softened. Pit highwall rock weathering and vegetation over the long term would blend with the color and texture of the natural landscape. Portions of the highwalls and benches would remain visible. Overall visual contrasts would be reduced to a level where they are noticeable but not dominant in the landscape, following successful reclamation and revegetation. Landscape modifications would be consistent with the suggested VRM Class III rating for the area.

Application: This measure would apply to the No Pit Pond Alternative and the Underground Sump Alternative.

Measure 22: The East Waste Rock Dump Complex would be extended back across the mouth of the pit to tie into the natural slope and partially screen the view of the northeast corner of the pit highwall.

Effectiveness: Views of the northwest portion of the pit highwall would be partially obscured.

Application: This measure would apply to the No Pit Pond Alternative and the Underground Sump Alternative.

4.8.4 Other Issues

Issue: Cultural resource protection.

Measure 23: GSM would prepare and execute a mitigation plan for the cabin located near the highwall, if it is threatened by cast blasting.

Effectiveness: A mitigation plan would ensure that the cabin is protected, or that historical data are properly collected and recorded before it is damaged or destroyed.

Application: This measure would apply to the Partial Pit Backfill With In-Pit Collection Alternative and the Partial Pit Backfill With Downgradient Collection Alternative.

4.9 UNAVOIDABLE ADVERSE IMPACTS

Unavoidable adverse impacts were addressed in the 1997 Draft EIS, Chapter IV, Section IV.Q. That analysis included evaluating unavoidable impacts that could result from expansion of mining activities, as well as reclamation activities. Implementation of the potential mitigation measures identified in the 1997 Draft EIS was to reduce most adverse impacts that were identified. This SEIS updates that analysis.

4.9.1 Technical Issues

The technical issues described and evaluated in this section relate primarily to stability, maintainability, and operating requirements of engineered structures and water management facilities as they relate to pit reclamation. The technical issues were evaluated in conjunction with the environmental and socioeconomic issues. The evaluation of the other issues assumed that the issues in the technical section function as designed and constructed. The success of the technical issues directly affects other issues.

Unavoidable impacts related to the technical issues include impacts associated with the pit highwall, groundwater effluent management system, storm water runon/runoff management, soil cover, water treatment, and flexibility for future improvements.

In alternatives that do not include large amounts of backfilling, it is expected that some portions of the pit highwall would be subject to raveling and limited sloughing, which are unavoidable. This movement could result in impacts to the dewatering system and pose safety concerns for workers in the pit. Limited environmental impacts would occur outside of the pit as a result of raveling and sloughing over time.

In regard to the groundwater effluent management system, the Partial Pit Backfill With In-Pit Collection Alternative would include a large amount of backfill and would encounter additional problems with pumping water from the pit. Due to the amount of backfill required and the characteristics of the backfill material, problems with operating and maintaining properly functioning wells and ensuring water can be effectively captured in backfill with low permeability are unavoidable. It cannot be reliably assured that these systems would function as designed. If the dewatering system fails, environmental impacts to regional groundwater could occur outside of the pit.

Storm water runon/runoff management activities would be required regardless of the alternative selected. The need for managing storm water diversions over acid producing waste would result in long-term maintenance needs.

The alternatives would result in the need for 3 feet of soil for covering the acid generating waste rock on 52 to 292 acres in the pit (Table 4-6), depending on the alternative. As needed, this soil would be removed from borrow areas on the mine site.

A small volume of soil would be lost to erosion during salvage and reapplication activities and following seeding until vegetation becomes established. The partial pit backfill alternatives are subject to settlement after reclamation, which could result in some limited soil loss and soil additions to reestablish grades. Under the No Pit Pond and Underground Sump alternatives, some soil on reclaimed areas in the pit would be lost adjacent to highwalls by raveling and sloughing rock.

Water treatment would be required regardless of the alternative chosen. GSM is bonded for long-term water treatment and this is unavoidable. Water treatment would result in the need to manage discharge water and sludge generated by treatment activities.

Opportunities exist for improvements to existing water management practices and plans in the future that could reduce contamination and provide lower cost treatment alternatives. Partial pit backfill alternatives could reduce the possibility of continued research and development of these opportunities within the pit backfill.

4.9.2 Environmental Issues

Unavoidable impacts related to environmental issues include impacts to groundwater quality and quantity, surface water quality and quantity, and reclamation plan changes.

Under the alternatives that maintain the pit as a hydrologic sink, dewatering the pit has reduced groundwater levels in the pit vicinity during operation. Continued pumping of groundwater for treatment, as part of reclamation, would result in lower groundwater levels for as long as pumping continues. The reduced groundwater levels could impact discharges from local seeps and springs. Intercepted pit water is removed from the local hydrologic system. During operation, this water is used in the processing circuit. Following mine closure and reclamation, most of this water would be returned to the local groundwater system in another drainage down gradient of the water treatment plant after treatment to avoid recontamination of that water in the flow path below the pit.

The Partial Pit Backfill With In-Pit Collection Alternative would include a large amount of backfill and would encounter problems with pumping water and maintaining the pit as a hydrologic sink. If the dewatering system fails, contaminated groundwater would flow along a path projected in the Partial Pit Backfill With Downgradient Collection Alternative.

Under the Partial Pit Backfill With Downgradient Collection Alternative, the regional groundwater system in the pit would return to the level before mining. The water table down gradient of the pit would be drawn down around the capture wells. This is an unavoidable impact of downgradient dewatering using a groundwater capture system.

The Partial Pit Backfill With Downgradient Collection Alternative would result in contaminated groundwater leaving the pit and entering the local groundwater system. This water would impact the groundwater quality to the point of collection. If collection is not 96 percent effective adverse impacts would result at the mixing zone boundary.

No direct adverse impacts to wetlands have been identified. Indirect hydrologic impacts could occur to area springs under all alternatives.

There are 156 to 158 acres of pit area under the No Pit Pond Alternative and Underground Sump Alternative that would be reclaimed as highwall and not revegetated.

Reclamation for all of the alternatives requires diversion of surface water flows around waste rock dump complexes and the pit.

No changes from the unavoidable adverse impacts discussed for the waste rock dump complexes in the 1997 Draft EIS, Chapter IV, Section IV.Q are expected as a result of the reclamation plans evaluated in this SEIS.

4.9.3 Socioeconomic Issues

Unavoidable adverse impacts related to socioeconomic issues include impacts to mining employment, tax revenues, mineral reserves and resources, and land use after mining. Impacts to mining employment and tax revenues would occur if GSM decides to stop mining Stage 5B if a partial pit backfill alternative is selected.

No unavoidable adverse impacts to access to future mineral reserves and resources have been identified for the No Pit Pond Alternative and the Underground Sump Alternative. The Partial Pit Backfill With In-Pit Collection Alternative and the Partial Pit Backfill With Downgradient Collection Alternative would place 47,000,000 cubic yards of waste rock and soil back into the pit. This backfill material would bury the remaining potential mineral resource and would potentially make it uneconomic for future open pit extraction of ore by increasing waste-to-ore strip ratios.

Long-term loss of 156 to 158 acres of native wildlife habitat for species such as mule deer would occur under the No Pit Pond and Underground Sump

alternatives. The alternatives that would result in the largest loss of mule deer habitat would also result in a small gain of habitat for other wildlife species, such as raptors and bats.

Unavoidable adverse impacts for land use include areas disturbed by mining activity and the loss of grazing resources in the Bull Mountain Allotment and Hill and Wilkerson Allotment.

4.10 SHORT-TERM USE VERSUS LONG-TERM PRODUCTIVITY

The 1997 Draft EIS, Chapter IV, Section IV.R addressed short-term use versus long-term productivity. This SEIS only addresses changes to productivity that would occur as a result of pit reclamation alternatives. Short term is defined as the life of GSM through closure and reclamation (2011). Long term is defined as the future beyond reclamation. Many of the impacts associated with all alternatives would be short term and would cease following successful reclamation.

Soil and vegetation short-term productivity would be reduced on the 56 to 58 acres of new disturbance under the partial pit backfill alternatives. Assuming revegetation is successful, and soil development and vegetation succession occur, long-term soil productivity would be restored. The permanent loss of 156 to 158 acres of native vegetation and wildlife habitat under the No Pit Pond and Underground Sump alternatives would be partially offset by productivity of the acreage revegetated with predominantly non-native species.

Noxious weeds are increasing in areas around the mine and across Montana. Regardless of control efforts, noxious weeds will increase on the pit disturbed area for all alternatives, affecting long-term productivity of desirable species. Plant community composition would be altered by the noxious weeds and control activities. This is an unavoidable impact of noxious weed presence and control.

4.11 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

The 1997 Draft EIS, Chapter IV, Section IV.S addressed irreversible and irretrievable commitments of resources. This SEIS only addresses changes to irreversible and irretrievable commitments of resources that would occur as a result of pit reclamation alternatives. Irreversible is a term that describes the loss of future options. It applies primarily to the effects of use of nonrenewable resources, such as minerals or cultural resources, or to those factors, such as soil productivity, that are renewable only over long periods of time. Irretrievable is a term that applies to the loss of production, harvest, or use of natural resources. For example, livestock forage production from an area is lost irretrievably while an area is serving as a mining area. The production lost is

irretrievable, but the action is not irreversible. If the use changes and the mine is reclaimed, it is possible to resume forage production. Irreversible and irretrievable impacts under all alternatives are similar to those analyzed in the 1997 Draft EIS.

One irreversible loss addressed in this SEIS involves the ability to adapt to future technologies. Prevention and treatment technologies for ARD are continually evolving and becoming more effective. For alternatives involving partial pit backfilling, the ability to adapt to future changes in technology may be limited.

The partial pit backfill alternatives would restrict access to future reserves and limit the potential for future mining and recovery of remaining mineral resources and reserves. This agrees with conclusions of the National Resource Council Report by Committee on Hard Rock Mining on Federal Lands, 1999, National Academy Press, Washington, D.C., that backfilling pits does limit the potential for future mining and recovery of remaining mineral resources and reserves.

4.12 ENERGY REQUIREMENTS AND CONSERVATION POTENTIAL

Energy for Stage 5B and the reclamation alternatives would be essentially the same as listed in the 1997 Draft EIS, Chapter IV, Section IV.T.

The Partial Pit Backfill With In-Pit Collection Alternative and the Partial Pit Backfill With Downgradient Collection Alternative would have increased diesel fuel consumption for grading slopes to 2H:1V and backfilling waste rock from the East Waste Rock Dump Complex into the pit. The life-of-project diesel fuel consumption increases from the 13,000,000 gallons for Stage 5B and the No Pit Pond Alternative to 22,000,000 gallons for the two partial pit backfill alternatives. Pumping from the underground workings under the Underground Sump Alternative would add a very minimal amount of electrical demand.